Electricity Costing and Pricing Study

Volume IV

The Demand for Electricity

October, 1976

ELECTRICITY COSTING AND PRICING STUDY

VOLUME IV
THE DEMAND FOR ELECTRICITY

Ontario Hydro
October 1976

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I. INTRODUCTION

Most of the factors affecting the demand for electric energy in the Province of Ontario are beyond the control of Ontario Hydro. Of those that lie within Ontario Hydro's control, the two most important are the price charged for electric energy and the quality of the service supplied. These, in turn, depend upon the amount and type of inputs employed in the business, upon the constraint of recovering the cost of these inputs, and upon the types of rate structures employed to recover these costs. Other factors which affect demand and are under Ontario Hydro's control are the amount of information supplied to the market and (to some extent) the results of research into the hardware and usage patterns of equipment using electricity.

Total revenues required in any given period are in part the result of investment and operating-decisions made at some earlier time in order to meet some forecast of demand, subject to a set of uncertainties which are dictated by the magnitude of forecast error, the performance of the equipment, and the general operation of the market upon the supply prices of the inputs.

Consequently, costs and prices today have been determined first by decisions to invest in plant and other inputs, based on of anticipations arising from demands of the past, and second by the prices of these inputs. The resulting demand, in turn, is determined, but only in part, by these prices.

There is no formal model that describes this state of affairs in quantitative terms. Nor is it possible to use one to predict when one is available with acceptable accuracy. Instead the process has tended to be subdivided into manageable components on the supply and demand sides respectively, with considerable human judgement entering into the making of decisions.

Econometric models yield results on total energy, which may be broken down into various end uses.

Econometric models are therefore potentially useful (a) for checking aggregate energy forecasts made by other means, and (b) for testing the sensitivity of electrical demand to changes in policy variables and in other variables.

During the late 1950s and early 1960s, attempts were made to assess the effect of natural gas from Western Canada upon the demand for electric energy - that is, the cross-elasticity of demand of the price of gas. A reduction of 50 per cent or so in the price of gas, had a considerable effect on the water-heating market, which tended to be linked to the space-heating market. Oil space heating, on the other hand, tended to be associated with electric water heating; and as long as that was so, oil and electricity tended to complement one another. But with the introduction of electric space heating in Ontario in 1959, oil and electricity tended to be competitive products. Since these two tendencies imply opposite signs for the coefficient of oil in an electricity demand function, it is not altogether surprising that current results on the effect of oil prices are somewhat ambiguous.

Other factors considered dominant in residential demand were income and the price of appliances.

The earlier findings were based on time series analysis rather than cross-section or pooled data, and were therefore not greatly trusted; but they were thought to be useful as an indication of the orders of magnitude.

With industrial demand, once natural gas arrived it tended for the most part to compete with coal. The availability of cheap natural gas may also have removed an impediment to Ontario's growth, and thereby served to increase the demand for electric energy. With the prospect of higher prices for coal and gas and with increasingly stringent environmental controls, it seems likely that gas may cease to be in any way complementary, and that in industry electricity will tend to become a substitute for both gas and coal. This is merely to warn that relationships may change over time.

The contents of this volume describe attempts Ontario Hydro has made in recent months to derive demand functions for various classes of electrical energy. Also included is a report of significant attempts (other bodies have made) to do the same for Ontario, and a report on the state of the art in other places.

Ontario Hydro's efforts have been concentrated in the residential field. The Mathewson model included in Appendix II is based on an explicit theory of consumer behaviour over time, in which consumers decide for themselves what appliances they wish to own, depending on their circumstances. The technical characteristics of appliances determine how much energy each can use; and the demand for electricity follows from that. The model is a comprehensive one, requiring data that did not exist in sufficient detail and bulk when it was run. There may, therefore, be problems with interpreting the results.

It will be noticed that, apart from Fuss and Waverman, no-one has made any explicit studies of commercial demand. In part, this stems from the heterogeneity within the sector and in the sparse data available. The general rate makes these data even harder to interpret. It was not possible to study the commercial sector, which was unfortunate, since that sector has been growing most rapidly.

In the industrial sector, the industrial structures and technologies of Canada and the United States were assumed to be similar enough to permit using a model developed for the United States. The NERA model used for this purpose is a simple constant-elasticity one. The values estimated for the United States underforecast the growth in demand in Ontario.

The positive conclusion one can draw from these efforts is that demand does respond somewhat to real reductions in price. However, the measurements made leave room for uncertainty, especially for the future, in which the real prices of all kinds of energy are expected to rise. Normally, one would expect increases in price to lead to greater price sensitivity; for example, the long-run effects of price increases might be a decline in capital investment in plant, or (alternatively) redesigning that plant to be more energy-efficient. However, since there are no effective secondary markets, declining investment involves capital write-off; and consequently the adjustment process is confined to new and replacement decisions which would tend to slow the adjustment process.

A further complication is that electricity is used for a wide range of purposes, each with its own set of responses to such factors as price, competitive prices, and incomes. This gives rise to demands for increasingly detailed analysis, in order to arrive at a properly weighted response of total demand. For predicting purposes, the forecasting-exercise thereby becomes more complicated without necessarily becoming more accurate.

II. THE DEMAND FOR ELECTRICITY

A. DETERMINANTS OF DEMAND

1. Theory

An individual consumer's demand for electricity is defined as the amount of electricity he wishes to buy in a given interval of time. An economist is interested in the factors which affect this demand. Because a specific length of time is involved, demand is measured in kilowatt-hours. A variable of great interest to electric utilities is peak demand, which is measured in kilowatts. For electricity, the economic variables that can vary over a period as short as a day are the price of electricity and congestion costs (blackouts, for instance).

What factors will affect the time and number of kilowatt-hours of electricity consumed? Before going into them in detail, one must first note that the demand for electricity is a derived demand. Electricity is rather a means to such ends as cooking food or driving buses. Since electricity is used in conjunction with some kind of capital, economists distinguish between two theoretical time periods:

1. *The short run.* It is assumed that the amount of capital equipment using electricity is constant, and the demand can be altered only by changing the intensity of its use: for instance, by turning thermostats down.
2. *The long run.* The amount of capital equipment using electricity is assumed to be variable. For example, if the price of gas increased greatly, residential customers might convert to electrical heating.

It should also be noted here that consumers have little scope for altering their demand for electricity in response to changes in price or income in the short run.[1]
The demand for electricity is thus approximately proportional to the stock of capital equipment. Some economists have therefore tried to explain the demand for electricity indirectly by explaining the stock of capital equipment.

Many factors affect the amount of electricity consumed. The main ones are listed here:

1. *The Price of Electricity.* One would expect that the higher the price of electricity, the lower would be the amount demanded. A complication arises because of the way electricity is usually priced. A customer does not face a single price, but rather a block rate schedule. This raises enough problems to warrant a separate section.
2. *Income.* One would expect that the larger a consumer's income was the greater his demand would be for electricity. This would probably be the result of owning a larger capital stock rather than short-run variations in demand.
3. *Prices of all Other Commodities.* Obviously some commodities will be much more important than others. If the price of gas rose greatly, one would expect some consumers at least to convert to electricity and so increase the demand for electricity. If the price of electric stoves increased one would expect people to buy fewer of them, and so bring the demand for electricity down. For electricity, gas is a substitute good and electric stoves are complementary goods.
4. *Housing and Demographic Characteristics.* Important variables in this category include new houses, the total number of apartments, and whether consumers live in an urban or a rural setting. The main difference between old and new homes is consumers in the former usually have a large fixed investment in, say, their space heating equipment, whereas consumers in the latter do not. This would tend to offset any (relatively) small changes in the variable costs, i.e., fuel prices, of running this equipment. Thus, with the inclusion of new homes as an explanatory variable one would expect the elasticity of demand with respect to fuel prices to be higher. Apartments are important for several reasons, the major one being that many are bulk-metered and as such are not included in the residential sector. If people in bulk-metered apartments behave differently to people in single-metered apartments with respect to their electricity consumption this will bias the results for the residential customers. Thus apartments are included as an explanatory variable to take out this effect and is expected to enter with a negative sign.
5. *Non-economic factors.* The main factor in this category is the weather, usually measured by heating degree days, cooling degree days or relative humidity. The effect of the weather is usually to change the intensity of use of equipment, e.g., if it is colder, space heaters are used more, although in the case of air conditioners it is expected to affect the stock, i.e., the 'muggier' it is the more people have air conditioners.

2. Price of Electricity

Customers are not charged a single, uniform price for electricity, but rather either a declining-block rate structure or a two-part peak and energy price. These raise theoretical problems when one tries to pick a single price to include in the demand function.

The appropriate price variable to include in the demand function is the price consumers respond to in making their decisions about use. Standard consumer theory has it that the marginal price is the right variable to use and this follows from the marginal conditions for maximizing utility within the limits of the budget. To maximize his utility, a customer must equate the ratio of marginal utility of the last unit of electricity he consumes, and the price of this last unit, to the same ratio for all goods. A consumer is not interested in a kilowatthour of electricity as such, but in the work electricity can do in (say) heating water. He needs, therefore, to know the relationship between the output of a particular good or service and the input of electricity. The utility he gets from consuming the last unit of this good or service must then be compared to the marginal price. But since the marginal price is a function of the amount of electricity bought for all purposes, he has to decide both whether to buy a given electric appliance, and how heavily to use it, at one and the same time.

The existence of a declining block rate structure of electrisity price also causes econometric problems which must be faced before any attempt is made to estimate the relationship. The chief problem is called the identification problem.

As the price of electricity goes up, one would expect people to demand less of it, and therefore, there to be an inverse relationship between the price of electricity and the quantity of electricity demanded. With a declining block rate system of pricing electricity, an increase in the quantity of electricity consumed causes the price (marginal or average) of this electricity to go down. This also is an inverse relationship between the price of

[1]Demand does vary over the short run, though, in response to weather. Moreover, in times of stress or emergency, public appeals have changed consumption significantly.

electricity and the quantity demanded. It is not a priori obvious how to separate the two inverse relationships postulated. Do low prices result in large consumption or does large consumption result in low prices? This is not an insurmountable problem as far as modern econometrics is concerned, as long as it is recognized that it exists.

The method most often used to remove the effect of quantity on price is to use a Typical Electricity Bill for some given level of consumption. Since Typical Electricity Bills are contaminated by flat-rate changes for water heaters a marginal typical bill is also sometimes used.

3. Estimation

The general functional form of the demand for electricity equation can be written as follows: $D_E = D(P_E, Y, P_{og}, T, NEF)$

where

1. $D_E$demand for electricity in kWh,
2. PE = price of electricity,
3. Y = income,
4. P_{og} = prices of other goods,
5. T = tastes and preferences, and
6. NEF = non-economic factors.

The problem of estimating is to assemble data for all these variables and to determine the relationship between them using statistical techniques.

4. Level of Aggregation

Finally, when embarking on an empirical study of the demand for electricity one must decide how to classify the data used. Generally, the dependent variable is not total kilowatt-hours, but rather sales to residential, commercial, and industrial customers separately. The variables affecting demand in these sectors are different enough, and so are the effects of the same variables, such as the price of electricity, to require separate equations.

In studies of the residential sector, the dependent variable is often consumption per capita, the justification for this being that total demand equals average consumption per capita times the number of users, and since there is nearly total saturation given the users involved, this variable will be completely unresponsive to economic stimuli.

The industrial sector includes a very diverse group of industries; and when this sector is being considered, one will probably want to take the differences into account.

B. SUMMARY OF MEASURES OF THE DEMAND FUNCTION

A certain amount of information will be summarized in the estimated coefficients on all the independent variables in the demand function. There are, though, some other summary measures, which are more widely known, easier to understand, and useful. These can be grouped under the general heading of elasticity of demand.

1. Elasticity of Demand

Elasticity is a measure of how much the dependent variable in a demand function responds to changes in an independent variable, all other variables remaining constant. More specifically, it is the relationship between a given percentage change in an independent variable and the resulting percentage change in the dependent variable.

Several elasticities are of interest:

a. The price elasticity of demand for electricity is the degree to which the amount of electricity demanded responds to changes in the price of electricity. Price elasticity of demand is interesting because of its relationship to total revenue; if, with a fall in price, the percentage change in the amount demanded exceeds the percentage change in price, while all other things remain constant, then total revenue will rise. Demand is then said to be elastic. If total revenue had fallen, one would have said demand was inelastic; and if revenue had stayed the same, one would have said the elasticity was unitary.

b. Income elasticity measures how much the amount of electricity demanded responds to changes in income; as incomes rise over time, how does that affect the demand for electricity?

c. Cross-elasticity of demand summarizes what happens to the amount of electricity demanded when the price of a related good changes. Thus, if the demand for electricity rises when the price of gas rises, these goods are said to be substitutes (that is, cross-elasticity is positive), while if the demand for electricity falls when the prices of large electric appliances rise, those goods are said to be complements (cross-elasticity is negative).

2. Measurement of Elasticity

The exact measurement of elasticity depends on the actual sizes of changes in the variables of interest. Two types are shown in the accompanying table.

1. *Arc elasticity: finite changes in variables:*

$$E = \frac{-\Delta Q}{\Delta P} \frac{\left(\frac{P_2 + P_1}{2}\right)}{\frac{Q_2 + Q_1}{2}} = -\frac{(Q_2 - Q_1)}{(P_2 - P_1)} \frac{(P_2 + P_1)}{(Q_2 + Q_1)}$$

$$= -\frac{(P_2 + P_1)}{(P_1 - P_2)} \frac{(Q_2 - Q_1)}{(Q_2 + Q_1)}$$

where

1. E = Price Elasticity,
2. Q = Quantity Demanded,
3. P = Price,
4. $_1$ = old (price and quantity demanded), and
5. $_2$ = new (price and quantity demanded).

The defect of this measure is that its value depends on the size of changes taken (which is essentially arbitrary).

2. *Point Elasticity = infinitesimally small changes in variables:*

$$E = -\frac{dQ/Q}{sP/P} = -\frac{dQ}{dP} \cdot \frac{P}{Q} = -\text{slope} \cdot \frac{P}{Q}$$

3. Elasticity and the Form of the Demand Function

The explicit functional form chosen for the demand function has implications for the nature of elasticity. If the function is linear, then elasticity will vary directly with price along the demand curve and with shifts in that curve. If the function is logarithmic, then elasticity is constant. While using a logarithmic form is often convenient, its implicit assumption of constant elasticity is subject to question. Insofar as high prices for a product tend to bring substitutes into competition, demand would tend to be more price elastic at higher prices and vice versa. This suggests a linear function, but there is no particular reason to believe demand functions are of constant slope throughout.

III. THE USES OF STUDIES OF THE DEMAND FOR ELECTRICITY

A. LOAD FORECASTING

A distinction must be made at the outset between the uses of past studies of the demand for electricity and the uses of studies which could be done. This can best be seen by considering the uses of demand studies for load forecasting. As was stressed in the previous section, studies have concentrated on explaining kWh sales not kW sales, although at first sight the latter should seem to be the more important variable. But sales of kilowatt-hours must be satisfied from capacity of some kind or other; and given the future growth of sales as now forecast, the corresponding growth in peak load is the main thing one needs to know to decide what kind of generating-capacity is needed. Thus while analysis of peak demand would be a useful aid to making this latter decision, it is not in fact the primary concern.

B. REVENUE ATTRITION

A second use of demand for electricity studies, and in particular the estimated price elasticity of demand, is in forecasting how much revenue will be lost when prices are increased. The relationship between the price elasticity of demand and total revenue was outlined in the last chapter. If demand is elastic, then if price rises, total revenue will fall: and it is important to know as precisely as possible by how much it will fall. If demand is largely inelastic, yet not altogether so, raising prices will also raise revenues, but the one rise will be less than directly proportional to the other.

C. RATEMAKING

The final use of demand studies is in designing rates. Price elasticity has some bearing both for determining costs and for setting rates based on those costs. Unless incremental costs are constant, they are determined by both supply and demand. Once costs have been determined, estimated price elasticities can play an important role in designing rates based on those costs. The main reasons for this, again, are the relation between price elasticity and total revenue, and the fixed revenue requirements of electric utilities. If when all rates are set at their respective long-run incremental costs the forecast total revenue exceeds the approved total revenue, then the utility must set each rate below the respective long-run incremental costs. To obtain the optimum individual deviations from long-run incremental costs, one must know the price elasticities of demand for the customers in the various rate categories. The object is to minimize having demand grow in response to rates which do not cover the cost of the resources consumed in meeting it. Thus if demand in a particular category is quite elastic, rates should be set at very little less than long-run incremental costs, since small decreases in price will lead to proportionately greater increases in demand. The opposite is true if demand is inelastic, and rates should then be set lower compared to the respective long-run incremental costs. The difference between prices and incremental costs varies inversely with the elasticity of demand, and so will minimize the inefficiency from setting prices below long-run incremental costs. This procedure has therefore come to be known as the inverse elasticity rule.

IV. SURVEY OF THE LITERATURE

A. INTRODUCTION

Articles on the demand for electricity now number well over a hundred. The bibliography to this volume lists only the main articles from the United Kingdom and the United States, with a separate section on Canadian articles; but it is still very long. Surveying all of these articles would thus be quite a task; and the truth is that even the excellent surveys already done focus on only a very small share of the total. [2]

This section, therefore, will concentrate on only the most important articles, although including also a sub section on Canadian articles, since the other surveys do not do so.

B. Important Studies in the United Kingdom and the United States

Since these are usually quite technical, a table is given explaining the main features of each. This, it is hoped, will let the reader to compare them more easily.

One can distinguish four main groups of writers:

1. Anderson;
2. Halvorsen;
3. Mount, Chapman, and Tyrrell and Cornell; and
4. The MIT Energy Workshop.

Since the articles within each group seldom vary as much as the groups, wherever possible one article from each group is chosen to represent the whole. Articles not fitting into any of these are nevertheless included if judged important.

C. SURVEY OF CANADIAN STUDIES

The main source for Canadian studies is the Institute of Policy Analysis of the University of Toronto. Except for the report of G.F. Mathewson and Associates to Ontario Hydro on residential demand, which is reviewed in the next chapter, they tend to focus on industrial demand. These studies bear comparison with those done anywhere in the world.

The most interesting of these studies is the study by Fuss and Waverman.[3]
because much attention is paid to the precise theoretical specification of the model. An outline of this study will follow to show how their theory is developed.

Fuss and Waverman estimate demand functions for electricity for the residential, industrial, and commercial sectors using pooled cross-section/time-series data for five regions (the Atlantic Provinces, Quebec, Ontario, the Prairies Provinces, and British Columbia) for the years 1958 to 1971. Attention in this summary is focused on the industrial sector, since Fuss and Waverman paid most attention to this sector.

Two basic models are considered in the industrial sector, the translog model and the logit model.

1. Translog Model

a. Theory

Firms are assumed to determine their factor inputs at two stages. At the first stage firms determine the optimal inputs of each of four aggregate factors of production: labour, capital, raw materials, and energy. The production function which summarizes the possible efficient combinations of these is assumed to be of the 'translog' variety 'in order to facilitate comparison with the U.S. studies'.[4]
Information contained in the production function can be combined with input prices to form a cost function which summarizes the costs of each of the input combinations to the firm. This takes the form of Formula 1 in the accompanying table.

If the firm is assumed to minimize costs, one can derive demand functions for each of the four inputs from the cost function. Writing these in terms of cost shares, they take the form of Formula 2 in the table.

Each of the four aggregate factors of production is in fact made up of several components. Fuss and Waverman assumed that once the firm had determined the optimum amount of each aggregate it would then determine the optimal mix within each category. One can do this if one assumes that the aggregate inputs are in some way separable in the production function. Since Fuss and Waverman were concerned only with the demand for energy, they assumed that the production function was weakly separable in energy. Thus the weakly separated cost function for energy can be written as Formula 3 in the table.

Again, if the firm is assumed to minimize costs, demand functions for each energy input can be derived; and these (again written in terms of shares of the total energy input) appear as in Formula 4.

$$\log C = \alpha_o + \sum_{\cdot i} \text{Ln } P_i + \alpha_a \text{ LnQ} + \sum_i \sum_j \gamma_{ij} \text{ Ln } P_i \text{ Ln } P_j + \Sigma_i \alpha_{iQ} \text{LnP}_i + \alpha_{QQ} (\text{Ln } Q)^2 \quad i,j = E,L,M,K \tag{1}$$

$$S_i = \alpha_i + \sum_j \gamma_{ij} \text{ Ln } P_j + \gamma_{iQ} \text{ ln } Q \tag{2}$$

$$S_i = \frac{P_i X_i}{\Sigma P_i X_i}$$

X_i = amount demanded of ith input

$$\text{Ln } P_E = B_o + \sum_i B_i \text{ Ln } P_{Ei} + \sum_i \sum_j B_{ij} \text{ Ln } P_{Ei} P_{Ej} \tag{3}$$

$$S_{Ei} = B_i + \sum_j B_{ij} \text{ Ln } P_{Eij} \quad i, j = 1 \ldots N \tag{4}$$

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[2]See for example L.D. Taylor in the *Bell Journal*, Spring 1975.

[3]M. Fuss and L. Waverman, *The Demand for Energy in Canada*, Institute for Policy Analysis, University of Toronto, February 1975.

[4]See vol. I, p. 40, and also Christensen, Jorgensen, and Lau, "Transcendental Logarithmic Production Frontiers", *Review of Economics and Statistics*, February 1973.

SUMMARY OF ECONOMETRIC ESTIMATES OF
THE DEMAND FOR ELECTRICITY

Residential Sector

Specification of Equations

	Type of Demand Function	Geographical Classification	Type of Data Used	Dependent Variable	Functional Form	Explanatory Variables: Own Price	Price of Substitutes	Income	Other	Estimated Elasticity
Houthakker-1951	Short Run	C	CS 1937-38	QE/ Customer	double log	M(-2)	Pg(-2)	$\frac{\text{income}}{\text{household}}$	K	- .89
Fisher & Kaysen - 1962	Short Run	S	CS-TS(A) 1946-57	QE	double log	A/P		personal income per $\frac{\text{capita}}{P}$		- .21 for New York State
"	Long Run	S	pooled CS-TS(A) 1946-57	change in K	double log	A/P	Pg	personal income per $\frac{\text{capita}}{P}$	P_k, Δno. of marriages, $\Delta\frac{\text{total electric customers}}{\text{total population}}$ price of gas-using substitute	inelastic
Houthakker & Taylor - 1970	Short Run	N	TS(A) 1947-70	$\frac{\text{QE/ Customer}}{P}$	linear	A/P			LDV, $\frac{\text{consumption/capita}}{P}$	- .13
"	Long Run	N	TS(A) 1947-70	$\frac{\text{QE/ Customer}}{P}$	linear	A/P			LDV, $\frac{\text{consumption/capita}}{P}$	-1.89
Wilson - 1971	Long Run	C	CS 1966	QE/ Household	double log	A*	Pg	medium family income	average rooms/household no. of degree days	-1.33
"	Long Run	SMSA	CS 1960	Saturation of ESH, EWH and ER	double log	A*	Pg	medium family income	average rooms/household no. of degree days	ESH -4.88 EWH -3.22 ER -1.98
Mount, Chapman & Tyrell - 1973	Long Run	S	CS-TS(A) 1946-70	QE	double log	A	Pg(-1)	income per capita	LDV, population, $P_k(-1)$ shift variable - mean January temperature	-1.20
Houthakker, Verleger & Sheehan - 1974	Short Run	S	CS-TS(A) 1960-71	QE/ Customer	double log	M	a) 100-500 kWh b) 100-250 kWh c) 250-500 kWh	income per capita	LDV	- .089 - .094 - .029
"	Long Run	S	CS-TS(A) 1960-71	QE/ Customer	double log	M	a) 100-500 kWh b) 100-250 kWh c) 250-500 kWh	income per capita	LDV	-1.0 -1.2 - .45

SUMMARY OF ECONOMETRIC ESTIMATES OF THE DEMAND FOR ELECTRICITY

Residential Sector

	Specification of Equations									
						Explanatory Variables				
	Type of Demand Function	Geographical Classification	Type of Data Used	Dependent Variable	Functional Form	Own Price	Price of Substitutes	Income	Other	Estimated Elasticity
Anderson - 1973 (R-1297)	Long Run	S	CS 1960&70	QE/ household	double log	A	P_{kE}, P_g, P_o, P_c, P_{bg}	income/ household	household size, detached & non-urban housing units as % of total, mean Dec. & July temperature	-1.12
"	Long Run	S	CS 1970	appliances of energy type i / appliances of energy type j	double log	.	Penergyi, Penergyj	income/ household (not imp.)	household size, detached & non-urban housing units as % of total, mean Dec. temperature	- .84

Anderson also estimates elasticities for various electricity-using activities as follows:

	Price Elasticities		Price Elasticities
Heating	-2.21	Food Freezing	- .8
Water Heating	-2.6	Multiple Room Air Conditioning	- .76
Cooking	-1.06	Central Air Conditioning	-1.09
Clothes Drying	-1.56	Dishwashing	- .9

	Type of Demand Function	Geographical Classification	Type of Data Used	Dependent Variable	Functional Form	Own Price	Price of Substitutes	Income	Other	Estimated Elasticity
Halvorsen - 1975	Long Run	S	CS-TS(A) 1961-69	QE/ Customer	double log	M/P	$\frac{Pg}{P}$	$\frac{\text{average income per capita}}{P}$	degree days, avg. July temp., time, avg. household size, % population rural, % population in multi-unit dwellings, index price of electrical equipment	-1.15

SUMMARY OF ECONOMETRIC ESTIMATES OF
THE DEMAND FOR ELECTRICITY

Industrial Sector

Specification of Equations

	Type of Demand Function	Geographical Classification	Type of Data Used	Dependent Variable	Functional Form	Explanatory Variables: Own Price	Price of Substitutes	Income	Other	Estimated Elasticity
Baxter and Rees - - 1968 - various industry groups	Long Run		CS-TS(Q) 1954-64	QE	log linear	A	Price of Several fuel Substitutes		Output	

Industry Group	Elasticities	Industry Group	Elasticities
Food, Drink, Tobacco	- .415	Textiles	-1.651
Chemicals	-1.069	Leather and Fur	-2.532
Non-Ferrous Metals	- .0843	Clothing	-2.444
Iron and Steel	-2.257	Timber	-3.181
Engineering	-0.588	Bricks	-0.738
Vehicles	-1.128	Paper	-1.083
Shipbuilding	- .904	Other Manufacturing	-1.207
Metals	-2.277	Mining and Quarrying	-2.017

	Type of Demand Function	Geographical Classification	Type of Data Used	Dependent Variable	Functional Form	Own Price	Price of Substitutes	Income	Other	Estimated Elasticity
Wilson - 1969 - various industry groups	Long Run	SMSA's	CS	QE	log linear	A,TEB	Pg,Pc,Po		VA	

Industry Group	Elasticities	Industry Group	Elasticities
Chemicals	-1.60	Other Machinery	-1.16
Paper Products	-1.64	Transportation & Equipment	-1.01
Primary Metal	-1.13	Leather Products	- .76
Stone, Clay & Glass Products	-1.30	Furniture	- .97
Textiles	-1.22	Printing	- .73
Lumber Products	-1.64	Rubber and Plastics	- .25
Food Products	-1.33	Petroleum & Coal Products	- .69
Electrical Machinery	-1.49		

	Type of Demand Function	Geographical Classification	Type of Data Used	Dependent Variable	Functional Form	Own Price	Price of Substitutes	Income	Other	Estimated Elasticity
Anderson - 1971 - primary metals	Long Run	S	pooled CS-TS 1958,62	QE/VA	log linear	A	Pc,Pco,Po		-average wage rate in primary metals industry -level of VA in primary metals industry -time	-1.94
Mount, Chapman and Tyrrell - 1973 -total manufacturing	Long Run	S	CS-TS(A) 1946-70	QE	double log	A	Pg(-1)	income per capita	LDV, population, $P_k(-1)$, shift variable - mean January temperature	-1.82

SUMMARY OF ECONOMETRIC ESTIMATES OF
THE DEMAND FOR ELECTRICITY

Commercial Sector

	Specification of Equations									
						Explanatory Variables				
	Type of Demand Function	Geographical Classification	Type of Data Used	Dependent Variable	Functional Form	Own Price	Price of Substitutes	Income	Other	Estimated Elasticity
Mount, Chapman and Tyrrell - 1973	Long Run	S	CS-TS(A) 1946-70	QE	double log	A	Pg(-1)	Income per capita	LDV, population, $P_k(-1)$, shift variable - mean January temperature	-1.36

SUMMARY OF ECONOMETRIC ESTIMATES OF
THE DEMAND FOR ELECTRICITY

Residential, Commercial and Industrial Sectors

	Specification of Equations									
						Explanatory Variables				
	Type of Demand Function	Geographical Classification	Type of Data Used	Dependent Variable	Functional Form	Own Price	Price of Substitutes	Income	Other	Estimated Elasticity
Cargill & Meyer -1971	NS		Monthly 24-hour load curve in one-hr. intervals for two cities 1965-1968	total system load per capita at time i	linear			personal income per capita	employment in manufacturing, time, avg. revenue/kWh avg. price/therm of gas	

KEY

A	Ex post average Price
(A)	Annual
A*	Average price for a fixed amount of electricity/month consumed per month
C	Cities
CS	Cross Section
ER	Electric Ranges
ESH	Electric Space Heating
EWH	Electric Water Heating
K	Stock of electricity consuming capital goods
LDV	Lagged dependent variable
M	Marginal price of electricity
N	National
NS	Not specified
P	General price level
Pbg	Price of bottled gas
Pc	Price of coal
Pco	Price of coke
Pg	Price of gas
Pk	Price of electricity consuming capital goods
PkE	Price of kerosene
Po	Price of oil
Q	Quarterly
QE	Quantity of Electricity (Total C)
S	States
SMSA	Standard Metropolitan Statistical Area
(-t)	Variable lagged t periods
TEB	Typical Electrical Bill
TS	Time Series
VA	Value Added

b. Estimation

Estimation of the complete model is accomplished in two stages. The system of energy input equations (4) is estimated subject to various constraints: for example, that the sum of the shares adds up to one. Substituting the parameter estimates from the estimated equations in this system into the weakly separated cost function (3), one obtains an estimate of the aggregate price of energy index. This estimate is then used as an instrumental variable in the second stage, in which the set of input demand functions (2) is estimated, again subject to various constraints.[5]

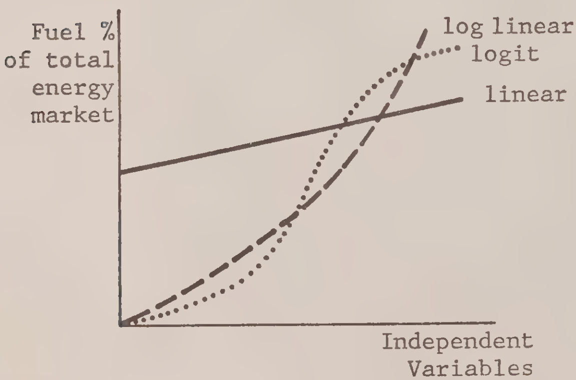
2. Logit Model

This is an extrapolative model, based on the market shares of the fuels under consideration. Since the dependent variable explained is the market share of a particular fuel, and this is limited to values between 0 and 1, this is where the name logit model comes from.

Fuss and Waverman took particular care in choosing functional form in this model. They chose the one they did because of unreasonable implicit assumptions in the more commonly used log and log-linear models. The linear form assumes it is as easy (or as hard) to capture an additional x per cent points of the market, no matter what level one has already obtained. It assumes that an increase in market share from 90 per cent to 100 percent is as easy as one from 10 per cent to 20; or again, that a fuel with 18 per cent of the market is as likely to increase its market share by a third (to 24 per cent). The logit model, in contrast, assumes that as a fuel captures a larger share of the market, it is progressively harder to increase market penetration, and that conversely as the market share decreases, it is progressively harder to lose the market share.

This difference between these three forms can be more easily seen diagramatically, as in Figure 1.

FIGURE 1



The demand function for each of the fuel types in logit form is:

$$l_{ijt} = do + d_i\gamma_{jt} + d_2 \frac{P_{ijt}}{P_{sjt}} + \Sigma\, dm\, Dm$$

l_{ijt} = logit of fuel type i, region j, time t,

$$= \mathrm{In}\left(\frac{Q_{ijt}}{T_{jt}} \Big/ \left(1 - \frac{Q_{ijt}}{T_{jt}}\right)\right)$$

- all volumes in output Btu's

- P_{sjt} - weighted average price of alternatives available to fuel i (weights are output Btu's, all prices in $'000 per mBTU's)

D_m - regional dummy

T_{jt} - total Btu's region j, time t.

Fuss and Waverman do not incorporate constraints into their logit model.

[5] Replacing P_E with the instrumental variable PEP_E

V. SUMMARY OF WORK ALREADY DONE FOR ONTARIO HYDRO

A. INTRODUCTION

Two studies of the demand for electricity have been done for Ontario Hydro by outside consultants. The first is a model of the residential demand for electricity in Canada, done by G.F. Mathewson and Associates of Toronto. The second is an application of the model of National Economic Research Associates, Inc. of New York City (NERA) of the industrial demand for electricity to Ontario Hydro data. A short summary of each of these will follow, the complete papers being included in Appendices II and III.

B. SUMMARY OF MATHEWSON MODEL[6]

1. Introduction

This study develops and tests a model of residential demands for electricity and natural gas. Pooled cross-section time-series data is used, the cross-section being four regions of Canada (Quebec, Ontario, the Prairies, and British Columbia) and the years 1958 to 1971.

Households can change their demand for electricity in two ways:

1. The main way, by changing the number of electrical appliances they have;
2. The more limited way, by changing the intensity of use of appliances already owned.

The Mathewson study concentrates on (1), assuming a fixed relationship between an appliance and the amount of electricity used, that is, that the intensity of use of applicances does not vary.

A distinction is made between heating-decisions, which require lump-sum investments, and appliance decisions, which are more continuous in nature. Households usually make the heating-decision only when they buy a new house or renovate an old one. At any other time the fixed costs tied up in the existing heating-system tend to dominate any variations in the costs of different heating-systems from changes in the relative prices of fuels prices. Mathewson therefore develops separate models to explain the heating and appliance demands for electricity in new and established dwellings.

2. Heating-Demand for Electricity

Not all households H(t) have the flexibility to adjust their heating-systems. Those that do are those involved either with net additions to housing-stock (completions of new houses c(t) less destructions of old ones d(t)) or those undertaking major renovations R(t). One can associate the typical heating-demand of new houses e_{hc} with the total number of new houses to obtain the heating demand of new houses. If data were available for d(t) and R(t), one could use the same procedure to determine the heating-demand for these classes. But they are not available (or so Mathewson assumes).

$$e_{hr}\ R(t) - e_{hd}\ d(t) = \emptyset^e\ H(t-1)$$

where:

e_{hr} = typical heating demand in renovated houses

e_{hd} = typical heating demand of 'dead' houses

In any year, actual heating-demand will vary from typical depending on the weather. Total heating-demand can thus be represented by the following equation:

$$\Delta E_h^e\ (t) = e_{hc}\ (t)\ c(t) + \emptyset\ H(t-1) + \gamma^e\ D(t)$$

where:

$\Delta E_h^e\ (t)$ = heating-component of residential demand for electricity

$D(t-1)$ = weather variable = heating degree days

$\emptyset^e$, γ^e are constants.

It is expected that:

$e_{hc}(t)$ will be affected by such cost factors as relative fuel prices, i.e.,

$$e_{hc}(t) = f(P_e, P_o, P_g)$$

where:

P_e, P_o, P_g = prices of electricity, oil and gas, respectively.

Combining equations (2) and (3), one obtains:

$$\Delta E_h^e\ (t) = g(P_e, P_o, P_g)\ c(t) + \emptyset^e\ H(t-1) + \gamma^e\ D(t)$$

3. Appliance Demand for Electricity

Mathewson also develops a model of the appliance demand for electricity, along more traditional lines. He obtains an equation explaining it, which takes the following form:

$$\Delta E_a^e = g\left([\Delta e_a(-1),\ P_e,\ P_g,\ P_d,\ Y]H(t)\right) \tag{5}$$

where:

E_a^e = appliance component of residential demand for electricity

$e_a(-1)$ = typical appliance demand by a household in last time period

P_d = user price of consumer durables

Y = income

<u>Total Residential Demand for Electricity</u>

This can be obtained from equations (4) and (5), and is the equation estimated by Mathewson.

<u>Results</u>

Of most interest are Mathewson's elasticity estimates. Reproduced here is part of Table 4, page 27.

		Heating Upper	Heating Lower	Appliance
EL P_e	1)	-6.07	-2.28	-.01
	2)	-6.86	-1.20	-.10
EL P_o	1)	-5.00	-1.88	
	2)	-2.29	-0.40	
EL P_g	1)	3.73	1.40	
	2)	4.71	.83	

Two points are of special note:

(a) The wide range of the elasticity estimates;

(b) Oil for heating and gas appliances may be complementary.

[6]G.F. Mathewson Associates, *Residential Demand for Electric Energy and Natural Gas: A General Model Estimated for Canada with Forecasts*, July 1976.

C. *AN ANALYSIS OF THE PRICE ELASTICITY OF INDUSTRIAL DEMAND FOR ELECTRICITY IN ONTARIO HYDRO'S SERVICE AREA*: REPORT TO ONTARIO HYDRO BY NERA, MARCH 1976

The primary purpose of this study is to ascertain whether patterns of the industrial demand for electricity during the period 1964 to 1972 suggest price elasticities consistent with those estimated by NERA using U.S. data. These estimates range around -0.5 for a typical mix of industries.[7]

The methodology used is to apply estimated coefficients, obtained using U.S. industrial data, to similarly defined Ontario industrial data, and to see how well the model predicts. The parameters of the U.S. model were estimated from a cross-section sample of Standard Metropolitan Census Areas for 1963. Sales of electricity were regressed on a measure of economic activity,[8]
the price of electricity, and the price of oil. These equations were estimated in logarithmic form.

Separate equations were developed for six categories of industry: textile-mill products, paper and allied products, chemicals and allied products, petroleum refining, primary metals, and all other industries. This had to be done because most industries employ unique technologies that may largely explain the differences in how intensively they use power. The rate of growth of total sales in the industrial sector was calculated after weighted elasticity coefficients for each industry were combined.

If the NERA model accurately predicts the observed pattern of industrial use in Ontario, it will be possible to draw inferences about the influence of output and price changes for electricity and alternative fuels on the demand for electricity.

In fact, the model consistently underpredicts (see Table 1). Although NERA gives some reasonable explanations of why this happened, they suggest estimating a complete industrial model from Ontario data to obtain fully trustworthy results.

TABLE 1

Actual and Predicted Growth in Use of Electricity by Major Industries in Ontario

1964-1972

	Annual Growth in Use 1964-1972	Predicted Growth In Use 1964-1972 Adjusted for Price and Value Added*	Difference Between Actual and Predicted Adjusted for Price and Value Added
	(1)	(2)	(3)
Textil Mill Products	8.2%	7.1%	-1.1%
Paper & Allied Products	2.4%	1.1%	-1.3%
Chemicals & Allied Products	5.1%	4.1%	-1.0%
Petroleum Refining	7.2%	3.3%	-3.9%
Primary Metals	4.8%	3.4%	-1.4%
Total Industries	5.0%	3.6%	-1.4%

Source: NERA Report, Table III-3.

$$^{*}\ \text{Annual Rate of Growth in Electricity Usage} = \left(\text{Annual Rate of Growth in Value Added}\right)^{\beta_1} \times \left(\text{Annual Rate of Growth in the Price of Electricity}\right)^{\beta_2} \times \left(\text{Annual Rate of Growth in the Price of Oil}\right)^{\beta_3}$$

[7] Page I-1.
[8] Value Added, or Value Added adjusted for 'location effect'.

VI. WORK IN PROGRESS AT ONTARIO HYDRO

A. INTRODUCTION

Initial research on demand for electricity in Ontario Hydro's service area has focused on electricity demand by residential customers. This customer class is only one of the major users of electricity. At present, two econometric models have been developed to describe residential demand for electricity and a third study using individual household data is at the preliminary stages of development. The main differences among these models can be described in terms of two characteristics: (1) the level of aggregation of end-uses of electricity, and (2) the level of aggregation of the consuming unit considered. One model which has been developed and completed is the Mathewson model presented in Appendix II of this report. Of the three studies, Mathewson's is the most aggregate in terms of both the characteristics described above. Mathewson disaggregated residential use into two components: space heating use and all other uses of electricity. Four regions of Canada are the consuming units. The second model developed for residential demand involved the application of NERA's methodology to data specific to Ontario Hydro's service area. The NERA model disaggregates end-uses of electricity into two components: uses of electricity for which competitive fuels are available, and those uses for which competitive fuels are not available. The competitive uses of electricity not only include space heating but water heating, cooking and clothes drying as well. The consuming units used in the analysis are towns in Ontario Hydro's service area. Finally, a third study of residential demand is being developed which will disaggregate end-use of electricity similar to the NERA model. However, the consuming unit modelled will be the individual household.

Each of these models differs in its approach to analysing residential demand for electricity, and therefore serves different purposes. Since the bulk of this chapter is devoted to discussing the second model, we will discuss the usefulness of such a model here. It should be noted, however, that aggregate models, such as that developed by Mathewson, should be considered in conjunction with more disaggregate models. Generally, the approaches generate similar results when properly interpreted. However, the advantage of a more disaggregate model of residential electricity lies in the additional information available in a disaggregate model. For example, it makes no sense to conclude from an analysis of total residential consumption that consumers' responses to increases in real electricity price will be determined by an elasticity of -I.0 or higher when that elasticity reflects, in very large measure, the appliance decisions of consumers rather than decisions on how to use those appliances. In a period of rising fossil fuel prices and, perhaps more importantly, limited availability of fossil fuels, residential consumers are hardly likely to substitute fossil fuels for electrical energy in space heating, water heating, clothes drying and cooking applications. Quite the contrary is the case as all available data strongly indicate. Consequently, the need to consider separately appliance decisions of residential customers and net usage of electricity by these customers once appliance decisions have been made flows directly from the need for a reasonable basis for making forecasts of future sales growth that are responsive to the realities of current and prospective market conditions both from the standpoint of demand and supply.

The remainder of this chapter will be organized as follows. Section B outlines the NERA methodology, summarizing the equations to be included in the model. Section C then discusses the application of this methodology to Ontario Hydro's service area. Specifically, the preliminary econometric specification of the model and the data used in the model are described. Section D presents the preliminary results of both the competitive-use model and the net-use model. The first model consists of equations explaining the stock of competitive appliances, while the second explains both the intensity of use of those appliances and also electricity use by appliances for which no competitive fuels are available. This section also contains a discussion of the limitations of our preliminary results. Finally, Section E describes ongoing research with the NERA model.

B. AN OUTLINE OF THE NERA MODEL OF THE RESIDENTIAL DEMAND FOR ELECTRICITY

NERA breaks down total residential sales in the following way: $R = C \times R/C$, where R = total residential sales in kWh and C = total number of residential customers of electricity. One does not expect changes in, say, the price of electricity to affect the total number of residential customers of electricity since virtually everybody uses some electricity nowadays anyway. NERA thus breaks down total residential sales in kWh in the above manner so that one can focus the analysis on the variable which really does and can change - the average consumption of residential customers.

There are two distinct decisions on the part of consumers which determine R/C:

1. the decision on how large the stock of electricity-using equipment should be.
2. the decision on how intensely to use that stock.

As far as the first decision is concerned, two separate markets of electricity exist: those electricity-using appliances for which substitutes using alternative fuels exist; and those which can be fuelled only by electricity. Since the reaction of customers to an increase in the price of electricity if substitutes are available will necessarily be different to that if no substitutes are available, NERA disaggregates average residential use in the following way: $R/C = RA/C + RN/C$, where RA = usage related to electricity-using appliances which have substitutes which use alternate forms of energy, and RN = net usage. NERA then develops separate models to explain the two components of average residential use.

1. Appliance-Related Usage

There are four electricity appliances for which competitive fuel sources are available. These appliances include space heaters, water heaters, cookers and clothes dryers. Appliance-related usage then represents some aggregate of the use of these four appliances. Specifically, appliance-related use per total residential customer is defined as follows:

$$\frac{RA}{C} = \sum_{i=1}^{4} A_i \times S_i$$

where

A_i = average use of appliance i by customers owning the electrical appliance.

S_i = saturation of appliance i as a pure ratio.

Computationally, this implies the following. S_i is defined as the number of customers owning electric appliance i divided by the total number of customers, or the proportion of residential customers owning a particular electric appliance, say, an electric space heater. Therefore, considering the calculation in greater detail:

S_i = number of customers owning electric appliance i divided by the total number of customers

A_i = total use of appliance i divided by the number of customers owning electric appliance

Since the numerator in S_i and the denominator in A_i are equal, they cancel, leaving the ratio of: total use of appliance i divided by the total number of residential customers

Summing this ratio for all four appliances yields appliance-related use per customer.

Thus in order to explain the level of appliance-related use, its two components must be explained.

a. A_i = average electricity use of appliance i

Average use figures are available for the whole of Ontario for the four competitive appliances. At this time, no such data are available for the individual municipalities and possible methods of developing behavioural equations relating use of space and water heaters to climate or conditions are being investigated.

b. S_i = saturation of electric appliance i

A set of behavioural equations was developed to explain the saturation of the four competitive appliances: space heaters; water heaters; cookers; and, clothes dryers. The equations postulated for each appliance can generally be described as follows: $S_i = f(P_e, P_{CF}, Y, HDD, H)$

where

1. S_i = saturation of electric appliance i, in some form
2. P_e = price of electricity
3. P_{CF} = price of competing fuels
4. Y = income per capita
5. HDD = heating degree days
6. H = collection of housing and demographic characteristics

The specific appliance equations used for the Ontario Hydro model and their econometric specification are discussed in Section C of this chapter. However, several things about these equations should be noted.

First, while all customers own some form of space-heating, water-heating and cooking, this is not true of clothes dryers. Therefore, an additional equation explaining total clothes dryers is estimated, before explaining electricity's share of the clothes drying market. Second, the role of income may be expected to play a major role in determining total clothes dryer saturation; its role elsewhere is indeterminate. Third, the relevant housing characteristics will differ across the four appliances.

2. Net Usage

Net usage is defined as usage by appliances for which no competitive fuels are available and above- or below-average use by the four competitive appliances, or the intensity of use of these four appliances. The factors affecting net usage will differ from those affecting the saturation of the four appliances. Specifically, competitive fuel prices are irrelevant in determining the intensity of use of the appliances, once the decision to own the appliance has been made. Included in net use is air conditioning use, which usually enters explicitly into the net use model to recognize approaching maximum saturations. In addition to air conditioning saturation, the variables in the net use model include price of electricity, income, housing, demographic and climate characteristics. The NERA model also separately estimates equations explaining the level of air conditioning saturation. However, given the low levels of air conditioning saturation in Ontario Hydro's area, we are not overly concerned with either its explicit inclusion in the net use model or a separate model describing that market.

C. APPLICATION OF NERA METHODOLOGY TO ONTARIO HYDRO SERVICE TERRITORY

I. Econometric Specification

As described in Section B, there are two sets of equations to be estimated:

a. equations describing the saturation of the four competitive appliances, and
b. equations describing net use and air conditioning.

We shall first discuss the econometric specification of the four competitive appliance models.

Several specifications of the appliance models were estimated. The regression results presented in Tables I to 4 reflect a general specification of each of the appliance markets which appear to be appropriate for the Ontario Hydro Service territory although none of the equations is to be considered final. We will turn to a discussion of the specification of the individual competitive-use appliance equations.

In the space-heating market the major competing fuels are electricity, utility gas and oil. Because electricity and gas are both to be preferred to oil in terms of cleanliness, it is reasonable to assume that, at the same level of income and prices, electricity and gas are preferred to oil. Two equations are then estimated, the first explaining electricity and gas's share of the space heating market and the second explaining electricity's share of the electricity and gas market. One would expect the second of these to be mainly determined by relative prices. Both of these equations were estimated in logit form.[9]

In the water-heating and cooking markets electricity and gas appliances comprise the whole market. Therefore, for both appliances explaining the saturation of electricity appliances is the same as explaining electricity's share of the electricity and gas market. A single equation was estimated for each appliance, with the ratio of the price of electricity to the price of gas as one of the explanatory variables to preserve the adding-up constraints.[10]

As was explained in Section B, estimation of electricity saturation of the clothes drying market should proceed in two steps. First, an equation explaining total clothes drying saturation is estimated and then a second equation explaining electricity's share of that market is estimated. The specification of this market should thus be somewhat analogous to the space heating market. However, gas's share of this market is so small that

[9] That is, the dependent variable takes the form log(s/l-s) where s is the saturation being measured. This variable has the advantage of ranging over all positive and negative numbers rather than being constrained to a 0.0 to l.0 interval. It must be emphasized that the coefficients in this form of equation are elasticities. The formula used to estimate electricity price elasticity is presented in the Technical Appendix (forthcoming).

[10] i.e., that electricity's share plus gas's share equals one. In the technical appendix a proof is given as to why this constraint is sufficient.

electricity's share of the electricity and gas market is virtually equal to one. We therefore estimated an equation explaining total clothes drying (i.e., electricity plus gas) and an equation explaining the saturation of electric clothes dryers which are almost equivalent.

In order to estimate a net use equation, appliance-related use must first be netted out of average use per customer. Although the appliance-related use of space and water-heating is related to weather conditions (as was noted earlier), at the present time data reflecting these relationships do not exist. Our estimates for the average use of these appliances are instead averages for the whole of Ontario. Therefore our specification of the dependent variable in the net-use model differs from the definition given in Section B-2 above, in that it includes the weather-sensitive component of space and water-heating use. We have included an additional explanatory variable in our net-use model, heating degree days, in order to take this factor into account.

2. Data

Ontario Hydro is a wholesaler of electricity as far as residential customers in Ontario are concerned. Electricity is first sold to the various municipalities in Ontario who then retail it to residential customers. The data base used in thus study is a cross-section of Ontario municipalities. Since such disaggregated data is only available in census years, the data relates to 1971. So that as large a percentage of the population of Ontario would be included in the sample while keeping the sample points to a reasonable number, municipalities with population greater than 10,000 were chosen. There are several sources of data.

a. Statistics Canada

The appliance, income, demographic and housing characteristics of the sample points were obtained from Statistics Canada. Included in the demographic characteristics was a breakdown of occupied dwellings by the principal type of fuel used for house heating, water heating and cooking.

b. Ontario Hydro

Data on the average consumption of electricity and typical electricity bills at various levels of consumption are published by Ontario Hydro. Also obtained from Ontario Hydro was data on the average usage of different appliances in Ontario. It should be stressed that these figures were available only for the whole of Ontario. Heating degree days were obtained from Ontario Hydro. As there are only a limited number of weather stations in Ontario, for many of the municipalities the figure for heating degree days is in fact an estimate. The meteorology department in Ontario Hydro provided these estimates. Finally, the saturation of both electricity and gas clothes dryers was obtained from the Hydro Appliance Survey.

c. Gas Companies

Gas prices were obtained from each of the individual gas companies in Ontario.

The raw data used in this study is listed in Appendix 4. As it is listed there, the data does not readily lend itself to meaningful interpretation. A more useful form of these data would be in the forms in which they were included in our models, e.g., the appliance data in the form of saturation ratios and not actual numbers. In subsequent reports, such revisions in the data presentation will be included.

D. PRELIMINARY RESULTS

In Tables One to Four, which follow, preliminary results obtained for the four appliances with competing fuels are set out. It must be emphasized that these results are preliminary and will change as we continue to refine the models in ways which will be discussed below.

Table 1

<u>Regression Results for Space Heating</u>

$$\ln\left[\frac{S_{SHE} + S_{SHG}}{1 - (S_{SHE} + S_{SHG})}\right] = \underset{(5.30)}{38.81} - \underset{(-2.89)}{4.55} \ln MTEB_1$$

$$\underset{(-6.93)}{-6.85} \ln P_g - \underset{(-1.72)}{1.82} \frac{TA}{TOD} + \underset{(2.19)}{1.85} \frac{NOD}{TOD}$$

$$\bar{r}^2 = .54$$

$$\ln\left[\frac{\dfrac{S_{SHE}}{S_{SHE} + S_{SHG}}}{1 - \dfrac{S_{SHE}}{S_{SHE} + S_{SHG}}}\right] = \underset{(-7.90)}{-17.52} + \underset{(6.95)}{6.00} \ln P_g$$

$$\bar{r}^2 = .44$$

Table 2

<u>Regression Results for Water Heating</u>

$$\ln S_{WME} = \underset{(-1.03)}{-4.64} - \underset{(-3.45)}{1.69} \ln\left[\frac{TEB_3}{P_g}\right] + \underset{(1.30)}{.40} \frac{NOD}{TOD}$$

$$+ \underset{(.64)}{.35} \frac{TA}{TOD} + \underset{(2.39)}{.96} \ln HDD$$

$$\bar{r}^2 = .39$$

Table 3

<u>Regression Results for Cooking</u>

$$\ln S_{CE} = \underset{(-4.3)}{-11.9} - \underset{(-2.7)}{.33} \ln\left[\frac{MTEB_2}{P_g}\right] + \underset{(.99)}{.27} \ln Y$$

$$+ \underset{(5.6)}{.91} \ln HDD + \underset{(2.2)}{.54} \frac{NOD}{TOD}$$

$$\bar{r}^2 = .50$$

Table 4

Regression Results for Clothes Drying

$$\ln\left[\frac{S_{CDE}}{1 - S_{CDE}}\right] = \underset{(-4.54)}{-19.60} + \underset{(2.09)}{.9} \ln \bar{Y} + \underset{(2.92)}{1.19} \frac{NOD}{TOD}$$

$$\underset{(-7.53)}{-2.70} \frac{TA}{TOD} + \underset{(5.39)}{1.33} \ln HDD$$

$\bar{r}^2 = .64$

$$\ln\left[\frac{S_{CDE} + S_{CDG}}{1 - \left[S_{CDE} + S_{CDG}\right]}\right] = \underset{(-2.31)}{-8.92} + \underset{(1.62)}{.62} \ln \bar{Y}$$

$$+ \underset{(3.46)}{1.26} \frac{NOD}{TOD} - \underset{(-10.66)}{3.42} \frac{TA}{TOD} + \underset{(1.98)}{.44} \ln HDD$$

$\bar{r}^2 = .70$

Key to Variables Used

S_{SHE} - ratio of total occupied dwellings using electricity as principal fuel to heat home

S_{SHG} - ratio of total occupied dwellings using gas as principal fuel to heat water

S_{WHE} - ratio of total occupied dwellings using electricity as principal fuel to heat water

S_{CE} - ratio of total occupied dwellings using electricity as principal fuel for cooking

S_{CDE} - saturation ratio of homes with electric clothes dryers

S_{CDG} - saturation ratio of homes with gas clothes dryers

TEB_1 - typical electric bill for five hundred kWh consumption

TEB_2 - typical electric bill for one thousand kWh consumption

TEB_3 - typical electric bill for twenty thousand kWh consumption

TEB_4 - typical electric bill for thirty thousand kWh consumption

$\left[MIEB_1\right] = TEB_4 - TEB_3$

$\left[MIEB_2\right] = TEB_2 - TEB_1$

P_g - typical gas bill for one hundred cubic feet consumption

$\bar{Y}$ - average income of individuals

TOD - total occupied dwellings

NOD - occupied dwellings built 1961 to 1971 inclusive

TA - total apartments

HDD - heating degree days

ln - natural log

$\bar{R}^2$ - coefficient of determination adjusted for degrees of freedom

Figures in parenthesis are "t" statistics.

Turning first to the regression results for space heating our results appear to suggest the following kinds of conclusions. Both electricity and gas prices play major roles in determining their share of the total market. It appears that new homes prefer electricity and gas over oil as the fuel for space heating. Given the high correlation of new homes with income (approximately .75) the result appears to support our original hypothesis that electricity and gas are prefered to oil if price and income warrant. Since most apartment houses are heated by oil the negative coefficient on the apartments variable is expected. The only significant variable found in explaining electricity's share of the electricity and gas market is the price of gas. The insignificance of the price of electricity in this equation may be explained in part by the substantial difference in electricity and gas prices at the time this study is concerned with.

Turning to the regression explaining the water-heating market, the fuel price ratio has the expected negative sign. However, the signs on the demographic and weather variables are not entirely satisfactory and at this time no conclusions in terms of these variables can be made.

The results for the electricity cooking equation for the most part appear reasonable. The fuel price ratio enters negatively as expected. Both income and new houses have a positive influence on electricity's share of the cooking market. The reason for the strong positive effect of heating degree days, however, is not readily apparent.

Finally, two sets of regression results are presented for clothes drying. For both the electricity and the electricity plus gas market the same independent variables have been included in the regressions and play similar roles. Income, new homes and heating degree days all have positive coefficients, as would be expected. Similarly, apartment houses have the expected negative coefficient. In both equations fuel prices are insignificant. As was expected, income played a significant part in the clothes-drying market, but not in the other three.

Table 5 presents the regression results for the net-use equation.

TABLE 5

Regression Results for Net Use

$$\ln(NU) = \underset{(-.81)}{-2.95} - \underset{(-1.32)}{.31}\ \ln MTEB_2 + \underset{(2.29)}{1.03}\ \ln \bar{y}$$

$$+ \underset{(2.30)}{.98}\ \frac{NOH}{TOD} - \underset{(-4.54)}{1.75}\ \frac{TA}{TOD} + \underset{(1.50)}{.00006}\ HDD$$

$$+ \underset{(.63)}{.003}\ AC \quad \bar{r}^2 = .47$$

Key to Variables Used

NU	- Net use
$MTEB_2$	- TEB for ith kWhC - TEB for 500 kWhC
$\bar{y}$	- Average income of individuals
TOD	- Total occupied dwellings
NOH	- Occupied dwellings built 1961 to 1971 inclusive
TA	- Total apartments
HDD	- Heating degree days
AC	- Saturation of single room and central air conditioning
$\bar{r}^2$	- Coefficient of determination adjusted for degrees of freedom

Figures in parenthesis are "t" statistics.

The coefficients on all the explanatory variables have the expected signs. Of particular interest are the coefficients on electricity price (-0.3) and income (+1.0), both closely corresponding to estimates obtained in similar studies in the United States. As expected, the stock of air conditioners, because it was so small, was not significant.

Using these preliminary results, one can obtain some idea of the magnitude of the elasticity of the price of electricity for residential customers. The own-price elasticity for this class is a weighted average of appliance-related and net-use elasticities, the weights being their respective proportions of average use. With respect to the electricity price elasticities estimated from the competitive-appliance models, we have obtained the following preliminary results: space heating, -2.0, water heating, -l.7, cooling, -0.3 and clothes drying, 0.0. Intuitively, the magnitudes of these elasticities appear reasonable. Electric space-heating, which is by far the largest use of electricity and which has two fuel competitors, has the largest own-price elasticity. The second largest use of electricity, water-heating, which at the time of this study was highly competitive with gas, has the second highest price elasticity. The relatively low elasticity in the cooking equation appears reasonable. The insignificance of electricity price in the clothes drying market given the very low levels of gas clothes dryers is a result to be expected. That is, gas does not appear to be a major competitor in determining the level of electric clothes dryers. Rather, the primary factors determining clothes dryer ownership (which is almost equivalent to electric clothes drying ownership) are income and weather conditions. The electricity price elasticity for net use is -0.3.

In our sample year, 1971, the relative proportions of total average use per customer of appliance-related usage and net usage were 58 per cent and 42 per cent respectively. Using these weights, the overall own-price elasticity is -0.94: that is, (-1.4 x .58) + (-0.31 x .42). This elasticity closely corresponds to estimates obtained in many other studies of the residential demand for electricity.

E. ONGOING RESEARCH

As we have emphasized throughout this chapter, the results from the application of the NERA model to Ontario Hydro's service area must be regarded as preliminary. Nevertheless, the results are encouraging, and further refinements are being explored.

The refinements of the appliance models will be focused on three main areas:

1. The first area of concern is the competitive role of fuels historically in Ontario Hydro's service area. The fuel prices included in the appliance equations reflect fuel supplies and price conditions only in 1971. However, since appliance saturations in 1971 reflect market conditions at least back through the 1960s, an analysis of historical competitive fuel prices seems warranted. Specifically, certain areas may have had historically low gas or fuel-oil prices, which may have diminished by 1971.
2. The second area for research is increasing the size of the data base to include rural areas within Ontario Hydro's service area. Places with a population greater than 2500 will be included, more than doubling the size of the present sample, which only includes places with more than 10,000 people. The benefits from increasing the sample size would be to introduce more variation in the economic and demographic variables, yielding better estimates of the true effects of these variables.
3. The third area of refinement is the incorporation of oil price explicitly into the space-heating model, and possibly into the water-heating model. However, our primary interest is in modelling the oil space-heating market, since this is the market where oil is the chief competitive fuel.

A second part of our research is concerned with further refining the net-use model. As was noted earlier, since space-heating use and (to a lesser extent) water-heating use are weather-sensitive, and weather conditions vary significantly across Ontario Hydro's service area, behavioural equations relating electricity use in the space- and water-heating applications to weather conditions will be developed. We shall then be able to estimate more accurately how much of the appliance-related use these two appliances account for. Developing these behavioural equations depends on having the relevant data available. One source may be the data on individual households which is the basis of the third residential demand study. These data include appliance characteristics and electricity consumption by household. While electricity consumption includes electricity used by all appliances, a model could be estimated using all-electric homes (that is, households with electric space and water-heating, cooking and clothes drying) as a data base.

Once the entire residential model has been estimated satisfactorily, the next stage in the analysis is to use the model to forecast future residential sales. It should be noted that the forecasts made using the NERA model should be interpreted as long-run ones, since the model has been constructed to forecast long-run trends rather than short-run fluctuations around the trend.

VII. RECOMMENDATIONS FOR FURTHER WORK

When the studies currently in progress are completed the kWh consumption of residential customers in Ontario will have been thoroughly analysed. Commercial and industrial customers are also extremely important and analysis of their kWh consumption has been very sketchy, both in the literature in general and at Ontario Hydro in particular. It is recommended, therefore, that separate studies of the kWh consumption of electricity in the commercial and industrial sectors by undertaken.

Leaving kWh sales, there are many aspects of the demand for electricity which need to be explored. The most obvious is the peak demand for electricity. It is recommended, therefore, that an analysis be undertaken of kW consumption. This would lead into many areas, the primary one of interest being peak pricing.

Finally, the simultaneous nature of the determination of the price of electricity and the quantity of electricity demanded has been noted. The residential model using individual household data is one attempt to solve this problem. The problem must be faced also, through, at a more aggregate level. This would involve the building of a larger scale econometric model of Ontario Hydro. Because of its importance, it is recommended that such a model should be built.

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RESIDENTIAL DEMAND FOR ELECTRIC ENERGY AND NATURAL GAS:

A GENERAL MODEL ESTIMATED FOR CANADA WITH FORECASTS

G.F. Mathewson Associates
5 Castle Frank Crescent
Toronto

July 1976.

INTRODUCTION

This study builds and estimates a residential demand model for electricity and natural gas. The features of this model differentiating it from other models are:

(i) a separation of household decisions into heating decisions, decisions requiring lumpy investments, and appliance decisions, decisions more continuous in nature;

(ii) a corresponding empirical finding that price and income elasticities are much greater at the decision time for lumpy heating decisions than for continuous appliance decisions;

(iii) an aggregation of households over regions facing different supply constraints on natural gas at any moment of time.

Recent studies by Anderson (1973) and Wilson (1971) estimate residential demand models for electricity. Anderson's paper stresses the notion of flexible versus inflexible consumers. Unlike Anderson's paper where the proportion of flexible consumers is a non-linear parameter to be estimated, flexibility in our model is associated with major changes in housing, either new or renovation, and thus major changes in the heating system. Our specification avoids the difficulties faced by Anderson in estimating this non-linear parameter. In addition, we estimate elasticities for on-going appliance accumulation. Although households with accumulated stocks of appliances may have reduced substitution opportunities due largely to thin secondary markets, such households have freedom in their decisions to augment their current stocks of durables.

Initially, our model was estimated using Canadian cross-sectional data in four regions from 1958 to 1971. Subsequently, observations across regions become available for 1972 and 1973. As elasticities of the sort estimated in this present paper are useful for forecasting demand, the additional observations were used to test the forecasting ability and thus, overall consistency of our model through time.

MODEL

To proceed more formally with the development of the demand equations, define heating and appliance components of residential demand for electricity or gas as $E_h^e(t)$, $E_h^g(t)$, $E_a^e(t)$, $E_a^g(t)$. ($E_j^i(t)$ represents units of energy type i = e(electricity) g(gas) for use j = h(heating), a(appliance)). Total fuel demands are then $E^e(t) \equiv E_h^e(t) + E_a^e$ for electricity and $E^g(t) \equiv E_h^g(t) + E_a^g(t)$ for gas. Separate models are developed to explain heating and appliance demand in new and existing residences.

First, we consider the heating demand for electricity. It is reasonable to expect weather conditions to influence heating requirements. Weather in our model is defined as $D(t)$, degree days below 65°F, and assumed to affect heating demand linearly. Thus, total heating demand for electricity is the sum of individual household demands plus a weather component:

$$E_h^e(t) = e_h(t)\ H(t) + \gamma^e\ D(t) \qquad (1)$$

where $e_h(t)$ defines the "typical" heating demand by a household, and $H(t)$ defines the number of households.

Taking a total differential of (1) yields:

$$\Delta E_h^e(t) = e_h(t-1)\ \Delta H(t) + H(t-1)\ \Delta e_h(t) + \gamma^e \Delta D(t) \qquad (2)$$

Households do not appear to adjust smoothly their purchase of heating equipment nor is there a developed rental market for heating equipment. Rather, purchases of furnaces are made infrequently and in lumpy amounts. Therefore, households which have the flexibility to adjust are those involved either with net additions to the housing stock i.e. completions of new dwellings $(c(t))$ less deaths of existing units $(d(t))$ or those undertaking major housing renovations $(r(t))$. Associated with each of these elements is a demand component per unit, e_{hc}, e_{hd}, e_{rd}, respectively. We would expect existing households not moving or renovating to maintain their previous demands for electricity net of any changes in weather conditions, i.e, $H(t-1)\ \Delta e_h(t) = 0$.

All of this permits us to rewrite (2) as:

$$\Delta E^e(t) = e_{hc}(t)\ C(t) + e_{hr}(t)\ r(t) - e_{hd} d(t) + \gamma^e D(t) \quad (3)$$

Now, consider appliance demand. The total demand for electricity for appliances is the sum of individual household demands so that $E_a^e(t)$ becomes:

$$E_a^e(t) = e_a(t)\ H(t) \qquad (4)$$

where $e_a(t)$ defines the "typical" appliance load by a household.

By taking a total differential, the change in appliance demand may be written:

$$\Delta E_a^e(t) = e_a(t)\ \Delta H(t) + H(t-1)\Delta e_a(t) \tag{5}$$

New households $(\Delta H(t))$ consume zero kwh of electricity in the previous period so their total demand in period t represents a change from their previous consumption. Consequently (5) may be written as:

$$\begin{aligned} \Delta E_a^e &\equiv (H(t-1) + \Delta H(t))\Delta e_a(t) \\ &\equiv H(t)\Delta e_a(t) \end{aligned} \tag{5'}$$

Substituting (5') and (3) into our definition of the aggregate change in the residential demand for electricity means that this demand may be written as:

$$\Delta E^e(t) = e_{hc}(t)C(t) + e_{hr}(t)r(t) - e_{hd}(t)d(t) + H(t)\Delta e_a(t) + \gamma^e\Delta D(t) \tag{7}$$

(7) is basically an identity derived from a definition of total residential electricity demand with assumptions about the flexibility and inflexibility of certain energy demands together with a weather factor. The first four terms on the right-hand side of (7) reflect flexible heating demand; the next factor reflects changes in appliance demand by new and existing households. This paper proceeds by developing structural models to explain these separate components of demand. To facilitate this analysis, each of these energy demand decisions is developed as a separable or independent process for the household.

The choice of the type of heating system for new completions is characterized as a modal choice. Each new completion is equiped for heating by one of three options -- electricity, oil, or natural gas. In fact, heating and appliance decisions may be dependent. For example, houses choosing oil heat usually have electric hot water and cooking while houses choosing gas as heat may have gas hot water and cooking. The choice is assumed to depend on the prices of the three fuels. In terms of more recent relative prices, it is important to note that fuels in any appliance-heating package may not remain immutable over all relative price changes. For example, historically oil and electricity have been complements as a heating-appliance package. More recently, the price of oil has increased relative to electricity. Sufficiently large relative price increases of this sort may result in oil and electricity becoming substitutes in home heating. This has implications for the interpretation of our empirical results.

Logically, the price of insulation should enter the choice for heating fuels as well. However, it appears that most houses historically have been insulated up to the standards of existing building codes which suggests that these codes, rather than the price of insulation, were the controlling factor.

Under these assumptions, the fuel choice decision for heating for each housing completion may be defined as:[1/]

$$e_{hc} \equiv \alpha^{e}(P_e, P_o, P_g) \qquad (8)$$

1/ Unless required for understanding, time subscripts are dropped as a convenience measure.

or in linearized form

$$e_{hc} \simeq \tilde{\alpha}^e + \alpha_e^e P_e + \alpha_o^e P_o + \alpha_g^e P_g \qquad (9)$$

Existing data do not permit direct measures of renovations or deaths of existing houses. Further, some experimentation suggests that there is no successful method of indirectly specifying the model to capture these effects. Consequently, we assume that

$$e_{hr} \cdot r - e_{hd} \cdot d \simeq \phi^e H(t-1) \qquad (10)$$

where ϕ^e is a constant of unknown sign.

Substituting this heating specification into (7) allows us to write the change in total residential demand for electricity as:

$$\Delta E^e = (\tilde{\alpha}^e + \alpha_e^e P_e + \alpha_o^e P_o + \alpha_g^e P_g)\, c + \phi^e H(-1) + \gamma^e \Delta D + H \Delta e_a \qquad (11)$$

Identical considerations for the residential demand for natural gas permits a similar specification of the change in aggregate residential natural gas demand. One important difference concerns the availability of natural gas for households over our sample period, 1958 to 1971. In 1956, the TransCanada Pipeline, a major East-West transmission line, was completed. This, together with expanding natural gas distribution networks, means that there was a dramatic expansion in gas availability for households during this period. Our model needs to account for these changes. To do this, define $\xi(t)$ as the portion of households with access to natural gas at time t, a variable bounded between zero and one. Assume new housing completions have access to natural gas at the same rate as existing households. Then, the corresponding equation for changes in total residential demand for natural gas is:

$$\Delta E^g = (\tilde{\alpha}^g + \alpha_e^g P_e + \alpha_o^g P_o + \alpha_g^g P_g)\, c\xi + \phi^e H(-1)\xi(-1) + \gamma^g \Delta D + H \Delta g_a \xi \qquad (12)$$

We now turn our attention to the demand for energy for appliance use. Unlike heating systems, appliance stocks using both natural gas and electricity may be held by consumers. Therefore, the choice of appliances is characterized as a continuous variable model. Here, the choice is between gas and electric equipment, with oil excluded as oil is used only to a small extent in hot water heating and nowhere else.

In the production of services[2/] from energy and durable goods by households we assume technological coefficients fixed at any moment of time. Under this assumption, we may aggregate units of durables and units of energy. If S_e measures units of electric durables and S_g measures units of gas durables, the associate energy packages are:

$$e_a = \theta S_e \tag{13}$$

$$g_a = \pi S_g \tag{14}$$

where θ, π are technologically optimal kwh or mcf per unit of electric or gas appliance respectively.

The total stock of durables may be defined through the appropriate selection of units as $S \equiv S_e + S_g$. Net additions to the stock are gross investment (I) whose price per unit is defined as p_I minus depreciation (δS) or

$$\dot{S} \equiv I - \delta S \tag{15}$$

In any period, dollars from a given income, Y , not spent on additions to the stock of durables or energy payments are spent on an all-purpose good whose price is set equal to one and, for convenience, whose utility is assumed additively separable from "energy" utility.

2/ It is important to note that there may be many such services (or characteristics) so that households do not necessarily choose one fuel exclusively or select that fuel that minimizes output BTU cost.

If households maximize the discounted stream of utilities over a household horizon that is infinite, the associated appliance and energy household problem under our assumptions becomes:

$$\text{Max } J = \int_0^\infty e^{-\rho t} U(Y - \theta P_e S_e - \pi P_g (S-S_e) - pI,\ S_e,\ S-S_e)dt \qquad (16)$$

subject to $\dot{S} = I - \delta S$, $I \geq 0$

where $U(.)$ is separable, quasi-concave function and ρ is a constant discount rate.

This is a straight-forward optimal control theory problem of the type found in Arrow and Kurz.[3/] Necessary and sufficient conditions for a solution are:

$$- U_1 \, p_I + \lambda = 0 \qquad (17)$$

$$- U_1 \, (ap_e - bp_g) + U_2 - U_3 = 0 \qquad (18)$$

$$\dot{\lambda} = \lambda \, (p + \delta) + U_1 bp_g - U_3 \qquad (19)$$

$$\dot{S} = I - \delta S \qquad (20)$$

$$\lim_{t \to \infty} e^{-\rho t} \lambda S = 0 \qquad (21)$$

Each of these equations affords an economic interpretation. λ is the dynamic shadow price on the stock of consumer durables. Equation (17) states that a consumer should buy an additional unit of durable goods at each point in time until the value of that additional unit equals the foregone untility from the equivalent expenditure on other things. Equation (18) states that a consumer should hold one additional unit of a durable using electric energy when the marginal

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3/ K.J. Arrow and M. Kurz, Public Investment: The Rate of Return and Optimal Fiscal Policy, (Baltimore: Johns Hopkins Press, 1970).

utility from this unit just equals the sum of (a) the foregone marginal utility from the gas-using alternative durable and (b) the marginal utility foregone on other things from the adjustment in the energy bill due to the additional durable using electrical energy. This equation determines the optimal mix of electrical and gas appliances. Equations (19) and (20) are the dynamic equations in the system. They describe the on-going optimal evolution of the stock of appliances for this household over time.

Substitution from equation (18) reveals that equation (19) may also be written as

$$\dot{\lambda} = \lambda(p + \delta) + U_1 a p_e - U_2 \tag{19a}$$

Equations (19) and (19a) permit identical interpretations for gas and electrical appliances. These equations are most easily interpreted in long-run equilibrium, i.e. $\dot{\lambda} = \dot{S} = 0$. Equations (16) and (16a) in long-run equilibrium state that the optimal stock of appliances occurs when the discounted net marginal utility from a change in the stock of durables just equals the implicit discounted price on durables.

Our interest in this model is an empirical one, i.e. how to use this model to derive a demand relationship for electricity for appliance use that can be estimated. In general, the procedure followed to derive such demand relationships is similar to that outlined in a different context in J.A. Rasmussen.[4/]

To accomplish this empirical objective, we first need to solve equations (17) and (18) for:

$$I = I(\lambda, S) \tag{22}$$

$$e_a = e_a(\lambda, S) \equiv \theta S_e(\lambda, S) \tag{23}$$

$$g_a = g_a(\lambda, S) \equiv \pi S_g(\lambda, S) \tag{24}$$

4/ J.A. Rasmussen, "Applications of a Model of Endogenous Technical Change to U.S. Industry Data", Review of Economic Studies, Vol. 40(2) No. 122, April 1973: 225-238.

Equations (19) and (20), the dynamic equations, evaluated at the optimal levels of the variables, I , e_a , and g_a under our assumptions yield one negative root (μ) and one positive root (μ') . These correspond to stable and unstable trajectories about steady state values, I^* , e_a^* , g_a^* .

By defining a vector of exogenous price and income variables as $V \equiv (p_e, p_g, p_I(\rho + \delta), Y)$ and linearizing the energy appliance demand equations about their steady-state levels (e_a^*, g_a^*) , we may define linear approximations to changes in individual demand equations for the on-going appliance use of electricity and natural gas:

$$\begin{bmatrix} \Delta e_a \\ \\ \Delta g_a \end{bmatrix} = \begin{bmatrix} (1+\mu(1-\delta))(1+\eta^e) & 0 & -\mu\frac{\partial e_a^*}{\partial V} \\ \\ 0 & (1+\mu(1-\delta)(1+\eta^g) & -\mu\frac{\partial g_a^*}{\partial V} \end{bmatrix} \begin{bmatrix} \Delta e_a(-1) \\ \Delta g_a(-1) \\ \Delta V' \end{bmatrix} \tag{25}$$

where $\eta^e \equiv \Delta\theta/\theta(-1)$, $\eta^g \equiv \Delta\pi/\pi(-1)$, technological change parameters.

Again, due to the changing availability of natural gas during the sample period, care must be taken in aggregating individual demands into regional demands.

Using $\xi(t)$, previously defined as the proportion of households with access to gas, we may differentiate between two cohorts of households each of which has its own energy demand:

(i) $HG(t-1) = \xi(t-1).H(t-1)$. These are households that existed last period and continue to exist in an area currently and previously serviced by natural gas.

(ii) $HG'(t-1) \equiv (\xi(t)-\xi(t-1))H(t-1)$. These are households that existed last period and continue to exist in an area serviced only currently but not previously by natural gas.

As well, there are new households but it matters to them only whether the area is now serviced by natural gas. Note that total consumers with access to natural gas is the sum of these groups, i.e.,

$$\xi(t)H(t) \equiv \xi(t-1).H(t-1) + (\xi(t) - \xi(t-1))H(t-1) + \xi(t)(H(t)-H(t-1)).$$

For cohort (i), natural gas demand is given by Δg_a in equation (25). For cohort (ii), natural gas demand is assumed to be $-\mu^S g_a^*$ where $-\mu^S$ (>0) is an adjustment rate for newly-serviced existing households; g_a^* is measured as the sum of (a) the long-run steady-state level of consumption that would have been used by these consumers in the previous year if gas have been available plus (b) changes in this long-run gas consumption due to changes in prices and incomes included in the vector of exogenous variables $(\frac{\partial g_a^*}{\partial V} \Delta V)$. These assumptions have advantages for aggregating demand.

Defining $g_a^*(-1) \equiv k_g E_a^g(-1)/HG(-1)$ and $E_a^{g^*} \equiv Hg_a^*$ and adding natural gas demands across cohorts permits us to write:

$$H\Delta g_a \xi \equiv [1+\mu(1-\delta)][1+\eta^g]\Delta E_a^g(-1)-\mu^S k_g E_a^g(-1).HG^1(-1)/HG(-1)$$
$$-\mu \frac{\partial E_a^{g^*}}{\partial V} H\Delta V \qquad (27)$$

The final model for the change in the residential demand for natural gas to be estimated is obtained by substituting (27) into (12) and adding a stochastic eror term:

$$\Delta E^g = (\tilde{\alpha}^g+\alpha_e^g p_e+\alpha_o^g+\alpha_g^g p_g)\xi c+\phi^g\xi(-1)H(-1) + \gamma^g\Delta D$$

$$+ [1 + \mu(1-\delta)][1+\eta^g]\Delta E_a^g(-1) - \mu^s k_g E_a^g(-1).HG'(-1)/HG(-1)$$

$$- \mu\frac{\partial E_a^{g*}}{\partial V}\Delta V + u_g \qquad (28)$$

Similar considerations yield a demand equation for the accumulation by households of appliances using electricity. Largely because of data limitations, no distinction is made between this electricity demand for households in areas serviced and not serviced by gas. The resulting demand equation for electricity for appliance use may be written as

$$H(-1)\Delta e_a = [1+\mu(1-)][1+\eta^e]\Delta E_a^e(-1) - \mu\frac{\partial E_a^{e*}}{\partial V} H(-1)\Delta V \qquad (29)$$

Substitution of (29) into (11), and the addition of a stochastic error term, yields an analagous model for the residential demand for electricity:

$$\Delta E^e = (\tilde{\alpha}^e + \alpha_e^e p_e + \alpha_o^e P_o + \alpha_g^e p_g)c + \phi^e H(-1) + \gamma^e\Delta D$$

$$+ [1+\mu(1-\delta)][1+\eta^e]\Delta E_a^e(-1) - \mu\frac{\partial E_a^{e*}}{\partial V} H(-1)\Delta V + u_e \qquad (30)$$

Equations (28) and (30) represent residential demand equations for natural gas and electricity that can be estimated with our data.[5/] All the variables in these equations are defined in Table 1.

Estimation

Our demand equations are estimated using Canadian data aggregated into four regions -- Quebec, Ontario, the Prarie Provinces,

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5/ Using oil data and our heating model, an attempt was made to estimate a residential oil demand model. This model failed. Further, as the recorded residential oil demand regressed against heating degree days gave for Ontario a coefficient on degree days that was not significant, we question the reliability of this oil demand data.

British Columbia -- over the period 1958 to 1971. The pooling of time series data for the different regions is required because there are too few observations to estimate the models for each region individually. Such pooling implicitly assumes that the demand relationship is stable across regions and over time.

The measurement of certain variables in these demand equations requires explanation. First, all housing completions are not homogeneous with respect to heating demands. To correct for this, and to smooth out the timing of completions, c is measured as a two year moving average of $\tilde{c}$ which is defined as:

$$\tilde{c} \equiv (\text{completion of dwellings}) \times [\sum_j (\frac{\text{dwelling starts type}(j)}{\text{dwelling starts}} \times f_j]$$

where (i) j is the type of dwelling units -- single family, semi-detached, and row; (ii) f_j is a set of "heating weights" from a provincial utility to reflect typical heating demand based on average size for each housing type: $f_{single} = 1$, $f_{semi} = .8$, $f_{row} = .6$.

As residential demand excludes apartments, the variable "number of households" has to be corrected for households in multiple family dwellings. To accomplish this, H is measured as the number of households times the proportion of single family dwellings in all dwellings.

Prior to 1963 due to high electricity prices relative to oil and natural gas, there was virtually no use of electricity for heating. To correct for this discontinuous adjustment in demand, first, define a dummy variable $\delta = 0$ prior to 1963 and $\delta = 1$ otherwise. Then, modify the change in total residential electric demand to:

$$\Delta E^e \equiv \delta + \delta\Delta E_h^e + \Delta E_a^e$$

The price and income levels and changes entering the demand equations should be expected price and income levels and changes. Based on a naive expectations hypothesis, realized levels and changes from the previous period are used for these expectations for these variables.

Degree days are measured as degree days below 65°F, a heating degree day. There is no equivalent measure for degree days above 65°F, so cooling degree days remain a left-out variable in this model.

Although the lagged endogenous variable in our model is $\Delta E_a^i(-1)(i=e,\ g)$, the previous change in residential consumption of energy of type i for the operation of household appliances, this variable is not directly measurable and is replaced by $\Delta E^i(-1)$, the previous change in total residential consumption, a substitution which biases downwards the estimate of $[1+\mu(1-\delta)][1+\eta^i]$.[6/]

Estimation of the residential demand model for natural gas requires a series for $HG(t) \equiv \xi(t).H(t)$ and $HG'(t-1) \equiv (\xi(t)-\xi(t-1))H(t-1)$. Neither of these nor $\xi(t)$ is available as published data, but both are estimated through an estimated $\xi(t)$. To accomplish this, for each of the four regions at time t, define PL(t) as the number of miles of natural gas distribution pipeline under 6 inches in diameter

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6/ Conceptually, this is tantamount to including in the regression a variable $\Delta E_\eta^i(-1)$ which should be omitted. This varialbe should have a zero coefficient but it is constrained by the specification to have the coefficient $[1+\mu(1+\delta)][1+\eta^i]$. If $\Delta E_\eta^e(-1)$ is uncorrelated with the other exogenous variables, its inclusion should biased downwards our estimate of $[1+\mu(1-\delta)][1+\eta^i]$, the magnitude of the bias depending on the relative magnitudes of the variances of $\Delta E_h^i(-1)$ and $\Delta E_a^i(-1)$.

(such pipe is used for distribution as opposed to transmission). $\xi(t)$ is estimated from a $PL(t)/H(t)$ series together with a series on the proportion of households in urban areas (areas with populations of ten thousand and over).[7/]

To facilitate forecasting, variables are measured in units relative to 1971 values, with Ontario values arbitrarily selected amongst the regions. Estimation results for residential electricity are presented in Table 2; estimation results for residential natural gas are presented in Table 3.

For natural gas, the lagged coefficient is not significantly different from zero and is dropped from the reported equation. This result indicates, measurement bias aside, that households in their continuous accumulation of gas appliance durables adjust very quickly to steady state levels. For electricity, the lagged coefficient is significantly different from zero. The presence of the lagged term raises one additional estimation issue.

Ordinary least squares (OLS) estimates of models that include endogenous variables in the presence of any autocorrelation in the error term yield inconsistent estimates of the parameters. To correct for any such autocorrelation, a Hildreth-Lu iterative (HILU) estimate on transformed variables is calculated and presented together with OLS estimates in Table 2.

7/ Details of this calculation may be found in Appendix A.

In general, the estimated equations "perform reasonably well" in terms of explained variance and the sign and significance of coefficients. The use of the HILU technique leads to a "Rho" variable (autocorrelative variable) that is significantly different from zero.[8/]

Assuming some autocorrelation leads to a better over-all fit and a slightly better forecast as measured by the relative root mean squared errors of the two forecasts.

Some preverse signs appear in coefficients in the estimated equations although in some cases these coefficients are not significantly different from zero. Thus, the signs on the price of oil in the electric heating model and the price of gas in the electric appliance model are both negative but insignificant when we would expect electricty and these fuels to be substitutes for these end-uses. Similarly, natural gas demand for appliance use appears to be an inferior good. One explanation for these results rests with the assumption on the separability of the heating and appliance decision. There is no guarantee this assumption holds. Thus, for example, the negative sign on the price of oil in the heating model may capture part of the traditional oil-electricity complementarity between heating and appliance decisions where gas was the alternative. Or, the negative sign of income for natural gas appliance demand may reflect a downward adjustment for appliances from the income effect for heating from the heating model which has captured some appliance demand in housing completions.

8/ In our case, Rho < 0 . The rationality for this result depends on what Rho represents. For example, if the error structure on the levels is $u_t = \rho u_{t-1}+(1-\rho)u_{t-2}+\lambda$ where λ has the usual properties and $1>\rho>0$. Then for first differences the estimated "Rho" should be negative.

Corresponding to each of the estimated equations in Tables 2 and 3, Table 4 reports the corresponding elasticities evaluated for Ontario in 1971, given our normalization on the data. For new housing completions in our model, the change in electricity demand for heating due to a change in the price of electricity may be written as:

$$\partial E_c^e / \partial p_e = \alpha_e^e c$$

Consequently, the corresponding elasticity becomes:

$$\varepsilon_{hc}^e \equiv \frac{\partial E_c^e}{\partial p_e} \cdot \frac{p_e}{E^e} = \frac{\alpha_e^e c p_e}{e_{hc} c}$$

As p_e for Ontario in 1971 equals one, then, for this price,

$$\varepsilon_{hc}^e = \frac{\alpha_e^e}{e_{hc}}$$

Although α_e is estimated in our equation, e_{hc} is not measurable from the data. An estimate, $\hat{e}_{hc}$, may be obtained by substituting values of prices for one year in the relevant part of the estimated equation. Thus, for Ontario in 1971 where $p_e = p_o = p_g = 1$ (i.e. prices are normalized for Ontario 1971). $\hat{e}_{hc} = .015$ and $\hat{\varepsilon}_{hc}^e = -6.06$. If we wish to measure the price elasticity of heating demand including renovations and deaths of houses, the $\hat{e}_{hc} = .040$ and $\hat{\varepsilon}_h^e = -2.28$.

Consequently, heating elasticities appear to lie between two extremes if our allocation of the load is correct. However, this allocation is only an estimate. Table 4 reports these boundary values for all heating elasticities for both estimated equations for electricity and the single estimated equation for natural gas as well as reporting a single estimate of the appliance elasticity for existing households.

One feature of the appliance elasticities for electricity deserves comment. To the extent that the estimate of the coefficient on the lagged endogenous term is biased downwards, the speed of adjustment on the appliance stock is biased upwards. This, in turn, biases downwards estimates of the long-run price and income elasticities of the appliance demand for residential electricity.

As the elasticity of the electricity and natural gas demand with respect to new completions is one by construction, the income elasticity of electricity for new completions depends directly on the income elasticity of housing demand.[9/]

Estimates of the income elasticity of housing demand in Canadian and American studies range from .35 to 2.3 with the majority of them between 0.6 and 1.0.[10/] Thus, the income elasticity of electricity demand should fall within this same range.

Forecasts for 1971 and 1972, the two additonal time periods of data that became available, are reported in Tables 2 and 3 for each of the four regions. Inspection reveals that generally, the model forecasts the growth rates reasonably well for the two years.

9/ Given, $\frac{\Delta E}{\Delta R}\frac{c}{E} = \frac{\partial\ \Delta E}{\partial\ \Delta c}\frac{\Delta c}{\Delta E} = 1$ in our model, then

$$\frac{\Delta E}{\Delta Y}\frac{Y}{E} = \frac{\Delta E}{\Delta R}\frac{c}{E}\frac{\Delta c}{\Delta Y}\frac{Y}{R} = \frac{\Delta c}{\Delta Y}\frac{Y}{c}$$

10/ These estimates are taken from Smith (1974:79-30).

Conclusions

The model of residential electricity and natural gas demand developed in this paper is composed of two parts:

(1) a modal choice model to explain the exclusive selection of one of the available choices of fuels for home heating (electricity, natrual gas, oil);

(2) a continuous choice model of durable appliance demand and consequently energy demand for appliances.

The resulting empirical estimates indicate that major changes in the heating system of houses are very price and income responsive, whereas appliance decisions of a more continuous nature are much less price and income responsive with stocks adjusting fairly quickly towards their long-run levels.

Both the electricity and natural gas models forecast changes in demand fairly accurately although a few caveats seem in order.

The results of this study and any other study using the same estimation period must be used with caution when forecasting or analyzing policy for periods in which the explanatory variables have changed greatly. The period analyzed in this study, 1958-71, involves relatively smooth changes in real energy prices and the other explanatory variables. For changes of the same order of magnitude and speed, the models could be expected to perform reasonably well. The greater the difference between the values of the explanatory variables in the forecast period and their mean values for the estimation period, the greater is the variance of the forecast errors. In addition, as the model is a linear approximation

to a more general demand function, the further one is from the point of approximation, the greater is the difference between the true relationship and its linear approximation. Further, the larger are the changes in exogenous variables, the more difficult it is to maintain the assumption of a constant rate of adjustment of the stocks of consumer durables.

Finally, there is the question of seasonal, daily and hourly fluctuations in demand. For electric and gas utilities, especially for decisions on peaking capacity and optimal rate design, the time distribution of demand over the year is as important as total consumption during the year.

Table 1

<u>Variables</u>

Δ	- indicates a one-year change in
E^e	- total residential electricity consumption
E^g	- total residential natural gas consumption
E^e_h	- residential electricity consumption for heating
E^e_a	- residential electricty consumption for appliances
E^g_h	- residential gas consumption for heating
E^g_a	- residential gas consumption for appliances
H	- number of households
e_h	- "typical" electric heating demand by a household
D	- degree days below 65°F in the months of January to May and September to December
c	- housing completions measured as a two year moving average of a single family, semi-detached and row housing completions weighted by an index of size for heating requirements
r	- housing renvoations
d	- deaths of existing housing stock
e_{hi}	- "typical" electric heating demand for housing change i = e,r,d
p_e	- the marginal price of electricty for residential consumers between 500 kwh and 1000 kwh per month, deflated by the consumer price index (CPI), lagged one year.
p_g	- the marginal price of gas to a typical residential heating customer deflated by the CPI, lagged one year

Table 1 (continued)

p_o	- the retail price of home heating oil, deflated by the CPI, lagged one year.
ξ	- proportion of households with access to natural gas
e_a	- "typical" electric appliance load by a household
g_a	- "typical" natural gas appliance load by a household
S_e	- the stock of durable appliances using electricity
S_g	- the stock of durable appliances using natural gas
S	- the total stock of durables
p_I	- Canadian consumer price index for consumer durables, deflated by CPI; $p_I(\rho+\delta)$, a user cost for durables, lagged one year
ρ	- real discount rate, estimated as the ninety-day rate on commercial paper minus a correctrion for anticipated inflation
δ	- a depreciation rate on consumer durables, assumed to be .10
θ, π	- technologically optimal kwh or mcf per unit of electric or gas appliance respectively
η^e, η^g	- the annual rates of change in energy inputs per unit of service produced by durables and energy for electricity and natural gas respectively, assumed to be -.01
λ	- a shadow price on stocks of appliances held by a "typical" household
Y	- personal disposable income per household, deflated by the CPI, lagged one year
HG	- an estimate of the number of households in an area serviced by gas

Table 1 (continued)

HG'	- an estimate of the number of old households in areas newly serviced by natural gas
k_g	- the ratio between long-run desired natural gas consumption and actual average natural gas consumption
δ	- a dummy variable equal to 0 prior to 1963, equal to 1 otherwise
$-\mu$	- the annual rate of adjustment for households towards their target stock of appliances
$-\mu^s$	- the rate of adjustment towards a target stock of gas appliances for existing households in the first year of newly established natural gas service

Table 2

Estimation of Residential Electricity Demand

(i) OLS

$$\Delta E^e = \underset{(.073)}{(.125} - \underset{(.026)}{.091p_e} - \underset{(.084)}{.075p_o} + \underset{(.021)}{.056p_g}\,)c + \underset{(.007)}{.025\,H(-1)} + \underset{(.017)}{.053\,\Delta D}$$

$$+ \underset{(.160)}{.329\Delta E^e(-1)} - \underset{(.052)}{.004H(-1)\Delta p_e} - \underset{(.055)}{.051H(-1)\Delta p_g} - \underset{(.014)}{.020H(-1)\Delta p_I(\rho+\delta)}$$

$$+ \underset{(.090)}{.063\Delta Y} - \underset{(.003)}{.0001\delta}$$

$R^2 = .900$

Forecasting

1) Correlation Coefficient Between Actual and Predicted = .768

2) Fit:

		Actual (% Change)	Predicted (% change)
Quebec	1971	6.8	5.5
	1972	8.3	4.9
Ontario	1971	5.5	6.9
	1972	5.4	6.0
Praries	1971	3.0	3.6
	1972	1.9	2.2
B.C.	1971	1.9	2.5
	1972	2.8	1.9

Table 2 (Continued)

Estimation of Residential Electricity Demand

(ii) Hildreth-Lu

$$\Delta E^{e} = (\underset{(.055)}{.038} - \underset{(.018)}{.048}p_{e} - \underset{(.059)}{.016}p_{o} + \underset{(.015)}{.033}p_{g})c + \underset{(.005)}{.010}\,H(-1) + \underset{(.016)}{.048}\,\Delta D$$

$$+ \underset{(.125)}{.678}\,\Delta E^{e}(-1) - \underset{(.045)}{.034}\,H(-1)\,\Delta p_{e} - \underset{(.046)}{.025}\,H(-1)\,\Delta p_{g} - \underset{(.023)}{.035}\,H(-1)\,\Delta p_{I}(\rho+\delta)$$

$$+ \underset{(.093)}{.084}\,\Delta Y - \underset{(.002)}{.002}$$

$R^2 = .924$ Rho = -.65 Standard Error (Rho) = .11

Forecasting

1) Correlation Coefficient Between Actual and Predicted = .822

2) Fit:

		Actual (% Change)	Predicted (% Change)
Quebec	1971	6.8	5.6
	1972	8.3	5.8
Ontario	1971	5.5	7.1
	1972	5.4	5.6
Praries	1971	3.0	3.9
	1972	1.9	2.2
B.C.	1971	1.9	2.8
	1972	2.8	1.7

Table 3

Estimation of Residential Natural Gas Demand

Regression

$$\Delta E^g = (\underset{(.156)}{-.268} + \underset{(.101)}{.300}p_e + \underset{(.212)}{.217}p_o - \underset{(.070)}{.143}p_g)c - \underset{(.039)}{.025}\,H(-1) + \underset{(.043)}{.182}\,\Delta D$$

$$+ \underset{(.159)}{.284}\,E^g(-1).HG'(-1)/HG(-1) + \underset{(.263)}{.508}\,H(-1)\Delta p_e - \underset{(.440)}{.209}\,H(-1)\Delta p_g$$

$$- \underset{(.064)}{.079}\,H(-1)\Delta p_I(\rho+\delta) - \underset{(.347)}{.766}\,H(-1)\Delta Y$$

$R^2 = .781$

D.W. = 2.56

Forecasting

1) Correlation Coefficient Between Actual and Predicted = .813

2) Fit:

		Actual (% Change)	Predicted (% Change)
Quebec	1971	2.1	2.6
	1972	- .6	-1.1
Ontario	1971	11.4	7.4
	1972	-5.0	1.9
Praries	1971	11.0	4.1
	1972	-4.2	-1.5
B.C.	1971	4.2	2.6
	1972	.9	- .3

Table 4

Elasticity Estimates

I Electricity Demand

i) Equation 1 (OLS)

Variable	Heating (upper)	Heating (lower)	Appliance (long-run)
$EL(p_e)$	-6.07	-2.28	-.01
$EL(p_o)$	-5.00	-1.88	
$EL(p_g)$	3.73	1.40	-.07
$EL(p_I(\rho+\delta))$			-.03
$EL(c)$	1	1	
$EL(Y)$			.10
μ			-.74

ii) Equation 2 (HILU)

Variable	Heating (upper)	Heating (lower)	Appliance (long-run)
$EL(p_e)$	-6.86	-1.20	-.10
$EL(p_o)$	-2.29	- .40	
$EL(p_g)$	4.71	.83	-.07
$EL(p_I(\rho+\delta))$			-.10
$EL(c)$	1	1	
$EL(Y)$			.24
μ			-.35

Table 4 (continued)

II Natural Gas Demand

Variable	Heating (upper)	Heating (lower)	Appliance (long-run)
$EL(p_e)$	3.70	2.53	.51
$EL(p_o)$	2.68	2.05	
$EL(p_g)$	-1.77	-1.35	-.21
$EL(p_I(\rho+\delta))$			-.079
$EL(c)$	1	1	
$EL(Y)$			-.77
μ			1

APPENDIX A

The proportion of households in areas serviced by gas is estimated using data on miles of distribution pipeline under six inches in diameter and the proportion of households in urban areas with population of 10,000 or more.

A plot of miles of distribution pipeline per household suggests two phases of expansion in each region: an initial expansion in the more densely populated areas and a subsequent expansion into less densely populated areas. As the number of households potentially serviced per mile of pipeline is lower in the latter areas, the increase in the number of potentially serviced households for a given increase in pipeline mileage is also lower. By choosing the appropriate years for each phase and plausible values for the proportion of households potentially serviced at the end of each phase, series can be constructed for the whole estimation period for the proportion of households in serviced areas. The resulting formula used to estimate the proportion of households in areas serviced by gas, ξ , for each region is as follows:

Quebec:	$\xi = .80\ PLH\ URB$	$PLH < PLH^*$
	$\xi = .80\ PLH^*\ URB + .40\ (PLH-PLH^*)\ URB$	$PLH > PLH^*$
Ontario:	$\xi = .18\ PLH\ URB$	$PLH < PLH^*$
	$\xi = .18\ PLH^*\ URB + .10\ (PLH-PLH^*)\ URB$	$PLH > PLH^*$
Praries:	$\xi = .22\ PLH\ URB$	$PLH < PLH^*$
	$\xi = .22\ PLH^*\ URB + .04\ (PLH-PLH^*)\ URB$	$PLH < PLH^*$
B.C.:	$\xi = .15\ PLH\ URB$	
	$\xi = .15\ PLH^*\ URB + .10\ (PLH-PLH^*)\ URB$	$PLH > PLH^*$

where PLH is miles of pipeline per thousand households, PLH* is miles of pipeline per thousand households at the end of phase 1, and URB is the urbanization ratio.

The availability series used in estimating the models is a simple two-year moving average of the series ξ .

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APPENDIX III

AN ANALYSIS OF PRICE ELASTICITY OF INDUSTRIAL DEMAND FOR ELECTRICITY IN ONTARIO HYDRO'S SERVICE AREA

A Report to
Ontario Hydro

by
National Economic Research Associates, Inc.

March 1976

I. INTRODUCTION

The primary purpose of this study is to ascertain whether patterns of industrial demand for electricity within Ontario during the period 1964 to 1972 suggest price elasticities consistent with those estimated by NERA using United States data. These estimates range around -0.5 for a typical mix of industries. The main conclusion of the study is that the Ontario data do suggest very similar underlying price elasticity values. Indeed, both the U.S. and Ontario data bases suggest the NERA results may be slight overestimates of true price elasticities (in absolute terms).

In order to facilitate an understanding of the factors which should be incorporated in a complete econometric model of industrial demand for electricity, Section II provides an overview of the underlying economic issues of industrial demand for electricity. The role played by the price of electricity, the prices of alternative fuels, such as utility gas and fuel oil, and the possibility of substitution among these fuels is emphasized. In addition, the importance of ascertaining the degree of substitution and/or complementarity among factors of production (such as between energy and capital) and the impact of increasing energy prices on the cost of production are discussed. Finally, consideration is given to the degree to which most econometric models have, to date, captured the economic issues we

outline. It is the objective of Section II to provide the reader with a theoretical framework against which to interpret the results we later present and against which to evaluate the attributes and shortcomings of the models considered.

Section III recapitulates the specification of the NERA model and presents the results of the comparison of the predicted growth rate[1] of industrial demand for electrical energy within Ontario Hydro's service territory with the actually experienced growth rate of demand. We conclude in Section III that the NERA model underpredicts (i.e., statistically underestimates) growth in industrial demand for electricity in Ontario Hydro's service area by approximately 1.0 percent for most industries.

Section IV expands the discussion of Section II and reviews two recent econometric models of industrial demand for electrical energy. The attempt of Section IV is to reconcile the slight disparity observed between the growth rates estimated by the NERA model and the actual growth rates in Ontario Hydro's service area. The fact that the NERA model consistently underpredicts growth during a period of rising real prices may suggest that our estimates of price elasticity are slightly high. Alternatively, this fact may

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[1] In this context, the term "predicted growth rate" means the statistically estimated growth rate; it does not refer to an estimate of future growth rates.

imply that the predicting equation is incomplete, i.e., that other significant causative variables have been omitted. Section IV provides a more complete discussion of the phenomena which might have contributed to the slightly low estimates. The two other models of industrial demand for electrical energy which are considered both incorporate at least some of the variables which may influence industrial demand for electricity but which are omitted in the NERA model. It is sufficient here to note that, even though these two models are substantially different from and perhaps more complete than the NERA model, both suggest price elasticities for electricity within close range of the NERA estimates. Therefore, it seems reasonable to conclude that the NERA estimates of price elasticity are, at worst, slight overestimations of real price elasticities (in absolute value). The NERA model's penchant for slight underprediction with Canadian data of historical growth may be due to improper specification of the price of competing fuel alternatives and/or to the omission of supplementary and complementary effects among the various factors of production, including energy inputs.

An appendix is included at the end of the study which contains, among other things, pertinent historical information on disaggregated industrial production. Historical data on substitution among different sources of energy within the industrial sector is also contained in this appendix.

The primary conclusions of this study are as follows: as mentioned, patterns of industrial demand for electricity within Ontario during the period 1964 to 1972 do suggest price elasticities consistent with those estimated by NERA using United States data. Consequently, it is our opinion that the NERA results can be used by Ontario Hydro for purposes of ascertaining the effect of electricity price changes on industrial demand for electricity.

With respect to the NERA model's usefulness in forecasting changes in industrial demand for electricity brought about by changes in variables other than price, it has already been noted that the model tends to underpredict growth in demand. The discussions (in Section IV) of the specification and conclusions of two other econometric studies and (in Section II) of the factors which should be incorporated in a complete econometric model of industrial demand for electricity suggest that further research is required to specify a model which fully captures the effects of all causative variables, including changes in energy prices and availability of competing fuels.

Our recommendations to Ontario Hydro are thus: (1) to consider the NERA estimates of electricity price elasticity with respect to industrial demand as applicable to Ontario Hydro's service area; and (2) to pursue further research in the area of forecasting changes in industrial demand for electricity, incorporating those factors discussed in Sections II and IV of this study.

II. THE INDUSTRIAL DEMAND FOR ELECTRICAL ENERGY: AN OVERVIEW OF THE UNDERLYING ISSUES

An ideal econometric analysis of the industrial demand for electricity should focus on at least three interdependent areas of research and should aim at providing answers to the following questions: (a) is the industrial demand for electricity responsive to a change in the prices of electricity and alternative fuels such as utility gas, oil, coal and LPG; (b) can electricity, or energy, be substituted for capital, labor or other types of raw materials; (c) does an increase in the price of electricity, or of energy, affect the average cost of production, and if so, does this effect have an impact on the demand for the final product?

In order to answer these questions, the econometric model must consider electricity, gas, oil, etc. as inputs into the production process of the typical firm on a par with capital, labor or other raw materials. Until the recent energy crunch, economists had concentrated their efforts on the study of production as being almost uniquely dependent on capital and labor and had omitted any reference to the role played by electricity, gas, etc. The dwindling U.S. supply of natural gas and the accelerating rise in the prices of oil and electricity have shifted the focus of attention. It is now widely recognized that energy, as a factor of production, can seriously distort the level of industrial activity if its supply is severely limited or if it is available only at a much higher price than previously.

Available econometric analyses of the industrial demand for electricity have stressed the long-run impact of changes in price of electricity on changes in consumption of electricity.[1] A comparison of estimated long-run price elasticities from these different analyses is shown in Table II-1. In the course of their research, economists have evolved three important criteria for estimating viable models of industrial demand for electricity. These criteria are:

1. The analysis must be disaggregated by type of industry since most industries are characterized by a unique technology that may explain, to a large extent, the differences in electricity intensiveness found among industries.

2. The analysis must consider the impact of price changes by end use. Industrial consumption of electrical energy is primarily for lighting, air conditioning and technologically oriented uses such as motor drive.[2] In a

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[1] See, for example, T. D. Mount, L. D. Chapman and T. J. Tyrrell, Electricity Demand in the United States: An Econometric Analysis (Oak Ridge, Tennessee: Oak Ridge National Laboratory, June 1973); John Wilson, "Residential and Industrial Demand For Electricity: An Empirical Analysis" (Ph.D. dissertation, Cornell University, June 1969) and; R. E. Baxter and R. Rees, "Analysis of Industrial Demand for Electricity," The Economic Journal, Vol. 78, No. 310 (June 1968).

[2] The 1968 U.S. industrial electricity consumption was divided as follows: electric drive, 79.6%; electrolytic process, 11.7%; direct heat, 5.4%; other, 3.3%. See, U.S. Office of Science and Technology, Patterns of Energy Consumption in the United States (U.S. Government Printing Office, Washington, D.C., 1972), Figure 11, p. 85.

long-run equilibrium situation, it can be assumed that there will be practically no possible substitution between electricity and other fuels for lighting, and it is doubtful that there will be any for air conditioning. Therefore, changes in the price of natural gas or oil would not affect the consumption patterns of electricity for these uses. This is not the case with technologically oriented uses, however, where over a sufficiently long time period it is possible to devise new technologies which utilize gas or oil instead of electricity.

3. The analysis must take into account the aggregation difficulties associated with variations in electricity intensiveness among sub-groups within the same industry and the influence of price differences among regions on the geographical location of industries.

Therefore, an answer to the first question raised above, namely, what is the effect of a change in the price of electricity and of other fuels on the consumption of electrical energy, is complex, especially in relation to the type of data usually available. It is believed, however, that an answer to the first question <u>only</u> would be insufficient for a thorough understanding of the problem at hand. If electricity, or energy, must be considered a bona fide factor of production, and we believe it must, then it is necessary to answer our second question: can there be any substitution between energy and other factors of production? This problem

is considered more fully in Section IV of this study but it is important to stress a number of points here. Since the prices of all energy sources are increasing and the availability of utility gas and, to some extent, locally produced oil is becoming increasingly uncertain, it is possible that these phenomena will exert a substantially depressing effect on the manufacturing sector. On the other hand, if substitution among factors of production is feasible, an infusion of capital or labor may be able to take up the slack created by the energy situation. Specific industries may thus decrease their consumption of energy either because prices are too high or because supplies are unavailable, and continue to produce at pre energy crisis levels.

Finally, given that we can evaluate the impact of the prices of electricity and of other fuels on the demand for electrical energy, and that the problem of substitution among factors of production can be solved, we still need to know the effect that a change in the price of electricity will have on the cost of production, and ultimately on the demand for the final product of a particular industry.

It is clear that answers to the three questions formulated above are of major importance not only to governmental agencies considering energy policies but also to private and public utilities that have to plan future energy supplies. An increase in the price of electrical

energy may lead to a cutback in consumption and, therefore, to a reduction in the need for additional generating capacity; moreover, a rise in the price of electrical energy may affect industrial production adversely if other investment opportunities are rendered more lucrative by comparison. Consequently, in the remaining sections of this study, we attempt to provide answers to these three main questions, but we are careful to indicate the limitations of available econometric models to answer these questions fully.

COMPARISON OF ESTIMATES OF LONG-RUN PRICE ELASTICITIES

Industry	Fisher and Kaysen[1]	Wilson[2]	NERA[3]
	(1)	(2)	(3)
Textile	-1.62	-1.22	-0.63
Paper	-0.97	-1.64	-0.56
Chemical	-2.60	-1.60	-0.91
Petroleum Refining		-	-0.91
Primary Metals	-1.28	-1.31	-0.98

[1]F. M. Fisher and C. Kaysen, A Study in Econometrics: The Demand for Electricity in the United States, (North Holland Publishing Co., Amsterdam: 1962).
[2]J. W. Wilson, "Residential and Industrial Demand for Electricity: An Empirical Analysis," unpublished Ph. D. diss., (Cornell University: 1969).
[3]Table III-2.

III. ECONOMETRIC ANALYSIS OF THE INDUSTRIAL DEMAND FOR ELECTRICITY

In this section, we compare estimates of growth in industrial consumption of electricity which are suggested by the NERA model to actual industrial consumption of electricity. The method utilized is to apply the estimated coefficients, obtained from using U.S. industrial data, to similarly defined Ontario industrial data. Our primary objective here is to analyze the predictive accuracy of the NERA forecasting model when applied to a comparably defined industrial data base for the Province of Ontario. The underlying supposition is that, if the NERA model accurately predicts the observed pattern of industrial consumption of electricity in the Ontario service area, it will then be possible to draw inferences as to the influence of output and of price changes in electricity and alternative fuels on the demand for electrical energy. We first consider the specification of the NERA model and then present the results of its application to Ontario Hydro's service area.

A. The NERA Model

The NERA model projects growth in usage by major industrial users as a function of the growth in output, the growth in the average price of electricity and the growth in the average price of alternative fuels. The functional

form of the model is such that estimated coefficients are elasticities.[1]

The parameters of the U.S. model were estimated from a cross-sectional sample of Standard Metropolitan Statistical Areas (SMSA) and states for the year 1963. Electricity sales were regressed against a measure of economic activity, the price of electricity and the price of a major competing fuel (oil).

In developing this model, we have focused on the need to disaggregate all manufacturing operations into separate industrial components. This need arises because different production processes make different uses of electricity. In particular, process uses of electricity differ greatly as does the proportion of electrical power used directly in

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[1] We would like to point out that the analysis of the industrial demand for electricity considered in this study makes use of only one such model developed by NERA. Kent Anderson, Senior Consultant at NERA's Los Angeles office, has also done extensive research in this area. His most recent model which analyzes sales to industrial customers is made up of data from eight different two-digit indusries and from a hypothetical ninth "all other" industry which uses coefficients that are averages for twelve additional manufacturing sectors. The model includes two alternative sets of submodels: one set using fuel-split models and one set using electricity-only equations. The fuel-split models estimate total energy demand by industry and then divide this total between electricity on the one hand and fuels taken together on the other hand. The electricity-only model is made up of two equations, one determining the price effect and the other determining the total amount of electricity purchased. In general, the results suggest slightly larger elasticity coefficients for the price of electricity, in absolute terms, than those reported in this section.

processes. Consequently, it makes no sense to study the sum total of industrial consumption, combining, for example, necessarily large users of electricity such as aluminum plants with less intensive users such as food processors. Our analysis, therefore, develops separate equations for projecting growth in electricity demand for each of five industries which are intensive users of electricity: textile mill products, paper and allied products, chemicals and allied products, petroleum refining and primary metals. In addition, a sixth category, all other industries, is considered.

Not surprisingly, these industries are also among the heaviest users of electricity in Ontario, accounting for 63.0 percent of total industrial electricity sales in 1972. Consequently, it is logical to apply the five equations estimated from U.S. data to Canadian data for these industries, after transcribing the Canadian Standard Industrial Classification (SIC) index into U.S. equivalents. (This procedure is shown in Table III-1.) As is done for the U.S. model, a rate of growth for total sales to the industrial sector in Ontario Hydro's service area is calculated after weighted elasticity coefficients for each industry are combined.

In addition to the disaggregation problem, we encountered an additional obstacle to accurately estimating the parameters of the equations from U.S. data. This second problem stems from the so-called "location effect," i.e., from variations in industry mix across geographical areas

due to the fact that, historically, energy-intensive industries have tended to locate in low-fuel cost areas in the U.S. In the absence of specific modifications of our econometric model, our estimates of price elasticity in two-digit industries would not be free from these location effects, since two-digit industries are simply aggregates of more homogeneous three-, four- and five-digit industries. These subindustries exhibit wide variations in their electric intensiveness. Failure to account for geographic variations in industry mix could lead to price elasticity estimates reflecting the relationship between electricity price and the type of industry locating in a particular area, rather than the relationship between electricity price and the industry's demand for electricity, net of location effects.

The following example is illustrative of this point. If electricity price is related to mix but not to intensity of use, a rise in electricity price in a particular area will only affect electricity consumption in that area insofar as it rises relative to other areas which represent viable alternatives. A general rise in price in all areas would have no effect on electricity usage and even a rise in a single area would only affect consumption in that area, not in the country as a whole. If, on the other hand, electricity price is really a determinant of intensity of use within a single, homogeneous industry, price rises in single areas or in the nation generally would have the effect of curtailing growth in industrial demand.

In estimating the parameters of the six equations, we attempted to control for these variations in industry mix across areas. Initially, value added was used as a measure of economic activity. We then substituted for value added a measure of economic activity adjusted for industry mix. This variable measures what electricity consumption in each industry would have been if, for each of the more detailed industries making up these aggregates, electricity consumption per dollar of value added had been the same as in the United States generally. We then examined the relationship between the price of electricity and the differences between actual usage in each industry and that which would prevail if consumption in each subindustry were at the national average. To the extent that actual consumption was below that predicted in areas in which the price of electricity was high and above that predicted in areas where the price was low, this would suggest that intensity of usage was varying in response to electricity price and not simply to the mix of component industries.

The parameters reported in Table III-2 for industrial equations are interesting in several respects. First, the equations have ouput elasticities which, in all cases, are approximately equal to one. Other things being equal, this suggests that the growth in electricity sales is nearly proportional to the growth in output. This assumption is largely verified in Figures III-1 through III-20, which show percentage

changes in the levels of value added, electricity consumed, and energy consumed for two-digit industries over the period of analysis. As can be observed from these figures, all three of these variables have, for the most part, tended to move together; this pattern is most consistent with respect to movements in electricity and value added. Similarly, Figures B-1 through B-19 of Appendix A, which show changes in the ratio of electricity per dollar of value added for two-digit industries over the historic period also tend to corroborate the econometric results. As can be observed from these figures, while the electricity per dollar of value added ratio has increased for a number of industries, these increases have been only moderate, i.e., the growth in electricity sales has been nearly proportional to the growth in output for most two-digit industries. Second, the electricity price elasticities observed in these equations are quite low (ranging from -0.26 to -0.98, as shown in Table III-2) by comparison to other estimates reported in the literature. Third, in three of the industries examined, electricity sales are responsive not only to changes in the price of electricity but also to changes in the price of oil. Thus, a rise in the price of energy will have a smaller impact on electricity sales than a rise in the price of electricity alone.

B. Application of the NERA Model to the Ontario Hydro Data Base

In order to measure the predictive accuracy of the NERA industrial model and its applicability to Ontario data,

we have used it to analyze the growth in sales of electricity to individual industries between 1964 and 1972. These results are described in Table III-3.

Three separate estimates of growth in consumption of electricity were made. The first set takes into account growth in value added, unadjusted for industry mix, and growth in the real prices of electricity and oil. The second set takes into account growth in value added, adjusted for industry mix, and growth in the real prices of electricity and oil. The third set takes into account only growth in value added, adjusted for industry mix. It is our judgment that the first methodology best predicts industrial growth in Ontario Hydro's service area. The second methodology, which adjusts for changing subindustry mix within the larger two-digit industries, underpredicts growth to a greater extent than the first method. This may be due to the fact that the kilowatt-hour per dollar of value added ratio for a number of these fast-growing subindustries increased over the period of analysis; this phenomenon would not be reflected in our corrections for industry mix which are based on 1963 ratios.[2] Therefore, based on comparisons of rates of growth in columns (1) and (2) (Table III-3), we observe that the

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[2] The graphs and discussion of trends in electricity consumption by key electric-intensive two-digit industries (Appendix A) are corroborative of the supposition that many of these subindustries probably increased in electric intensiveness.

NERA model consistently underpredicts growth in electricity consumption during the period 1964 to 1972 by approximately 1 percentage point, except for the petroleum refining industry where the NERA model underpredicts growth by 3.9 percent. The disparity between actual and predicted values may be attributable to the influences of such omitted factors as the price of capital, the price of labor and the price of materials. Some of the disparity may also be explained by the shift from self-generation to procurement of electrical energy that may have occurred during this period and which is not accounted for by the model. The net impact of the omissions discussed above probably results in elasticity estimates for the price of electrical energy that are too high. As a consequence, a forecast will overpredict consumption when real prices are increasing. In the United States, the real price of electricity declined over the period 1963 to 1971, a fact consistent with the NERA model's overpredicting the growth in consumption for that period (Table III-4). In Ontario, the opposite situation resulted, i.e., the real price of electricity increased slightly for most industries, a fact consistent with the NERA model's underpredicting the growth in consumption during the period analyzed.[3]

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[3] An example may illustrate this point more clearly. Let us assume that the price elasticity for industry X is -0.6. If, during a ten-year period, the real price of electricity went down by 2.0 percent, the end result would have been to increase consumption by 1.2 percent. On the other hand, if the price had gone up by 2.0 percent, the impact would have been to decrease consumption by 1.2 percent.

In general, we may conclude from the results that the demand for electricity by individual industries responds to a change in output (value added) and, to a more limited extent, to a change in the price of electricity. In addition, for some industries, the price of oil is a significant variable. From these results (which are also confirmed by other studies), it is tempting to conclude that, in the future, higher electricity prices will reduce growth in industrial demand for electricity within selected manufacturing industries. Furthermore, it is tempting to infer that higher electricity prices will bring about increased electricity conservation.

However, there are at least three problems associated with this type of reasoning. It is, in part, to the consideration of these problems that we direct our attention in Section IV. As explained in the introduction of this study, we review two other econometric studies of industrial electricity demand in Section IV. Our attempt is to explain the slight disparity observed between the growth rates predicted by the NERA model and the actual growth rates in Ontario Hydro's service area. We do this by evaluating empirical findings in light of the theoretical considerations which follow.

U.S. EQUIVALENTS OF CANADIAN TWO-DIGIT STANDARD INDUSTRIAL CLASSIFICATION INDEX

	United States	Canadian
	(1)	(2)
Textile Products	22	18,23
Paper Products	26	27
Chemicals and Chemical Products	28	37
Petroleum Refining	29	36
Primary Metals	33	29

ESTIMATED ELASTICITIES OF MANUFACTURING
DEMAND FOR ELECTRICITY IN THE UNITED STATES

Industry	Output Elasticity	Electric Price Elasticity	Alternative Fuel Price Elasticity[1]
	(1)	(2)	(3)
Textile Mill Products	1.18	-0.63[2]	-
Paper and Allied Products	0.98	-0.56[2]	0.41
Chemicals and Allied Products	0.98	-0.91[2]	0.27
Petroleum Refining	0.98	-0.91[2]	-
Primary Metals	1.03	-0.98[2]	1.11
All Other Industries	0.92	-0.26[3]	-

[1]Assumes oil is the alternative fuel.
[2]Significant at the 5 percent level.
[3]Significant at the 10 percent level.

TABLE III-3

ACTUAL AND PREDICTED GROWTH IN USAGE OF ELECTRICITY BY MAJOR INDUSTRIES IN ONTARIO

1964 - 1972

		Predicted Growth in Usage 1964-1972			Difference Between Actual and Predicted		
	Actual Growth in Usage 1964-1972	Adjusted for Price and Value Added[1]	Adjusted for Industry Mix and Price[2]	Unadjusted for Price and Value Added[3]	Adjusted for Price and Value Added	Adjusted for Industry Mix and Price	Unadjusted for Price and Value Added
	(Percent)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Textile Mill Products	8.2%	7.1%	6.4%	7.0%	-1.1%	-1.8%	1.2%
Paper and Allied Products	2.4	1.1	0.3	1.0	-1.3	-2.1	-1.4
Chemicals and Allied Products	5.1	4.1	3.1	4.9	-1.0	-2.0	-0.2
Petroleum Refining	7.2	3.3	3.5	4.5	-3.9	-3.7	-2.7
Primary Metals	4.8	3.4	6.3	6.3	-1.4	+1.5	+1.5
Total Industries	5.0	3.6	-	4.5	-1.4	-	+0.5

$$^{1}\left(\text{Annual Rate of Growth in Electricity Usage}\right) = \left(\text{Annual Rate of Growth in Value Added}\right)^{\beta_1} \times \left(\text{Annual Rate of Growth in the Price of Electricity}\right)^{\beta_2} \times \left(\text{Annual Rate of Growth in the Price of Oil}\right)^{\beta_3}$$

$$^{2}\left(\text{Annual Rate of Growth in Electricity Usage}\right) = \left(\text{Annual Rate of Growth in Adjusted Value Added}\right)^{\beta_1} \times \left(\text{Annual Rate of Growth in the Price of Electricity}\right)^{\beta_2} \times \left(\text{Annual Rate of Growth in the Price of Oil}\right)^{\beta_3}$$

[3] Estimated by multiplying average kilowatt-hour consumption per dollar of value added in 1972 in each subindustry at these industry aggregates, then finding the annual growth rates between 1964 and the estimated 1972 consumptions.

ACTUAL AND PREDICTED GROWTH IN USAGE OF
ELECTRICITY BY MAJOR INDUSTRIES IN THE UNITED STATES

1963 - 1971

	Growth in Usage 1963-1971	Predicted Growth in Usage (1963-1971) Adjusted for Price[1]	Predicted Growth in Usage (1963-1971) Unadjusted for Price[2]	Difference Between Predicted and Actual Adjusted for Price	Difference Between Predicted and Actual Unadjusted for Price
	(Percent)				
	(1)	(2)	(3)	(4)	(5)
Textile Mill Products	6.43%	7.99%	6.13%	1.56%	-0.30%
Paper and Allied Products	5.42	6.52	4.54	1.10	-0.88
Chemicals and Allied Products	5.87	3.98	5.09	-1.89	-0.78
Petroleum Refining	6.38	7.20	5.05	0.82	-1.33
Primary Metals	4.81	5.89	4.28	1.08	-0.53
Total Manufacturing	6.11	5.99	5.31	-0.12	-0.80

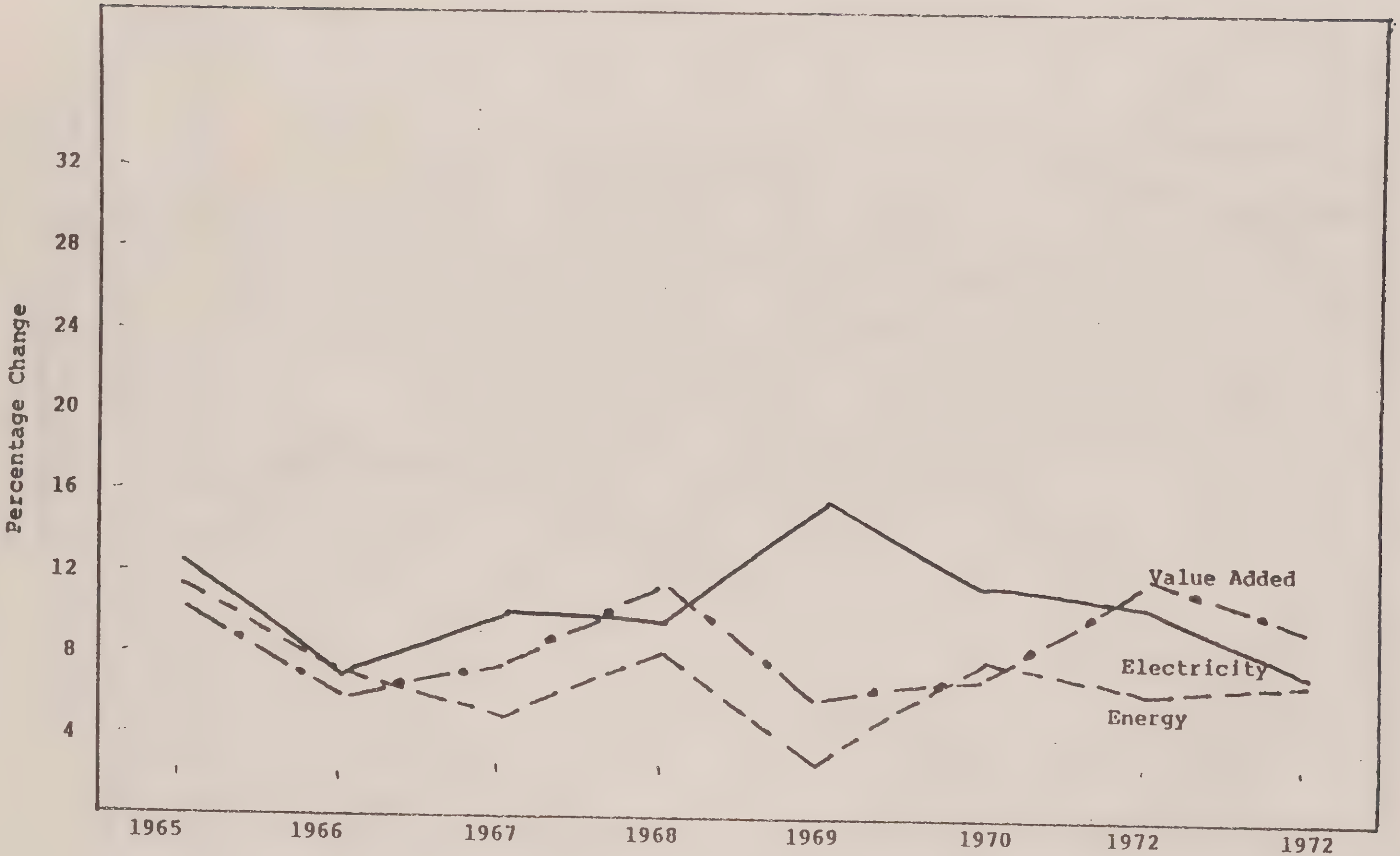
[1]Estimated based on elasticities in Table III-2.
[2]Estimated by multiplying average kilowatt-hour consumption per dollar of value added in 1963 by value added in 1971 in each subindustry at these industry aggregates, then finding the annual growth rates between 1963 and the estimated 1971 consumptions.

Source: Cols. (1), (2)&(3): Data on value added, U.S. Department of Commerce, Annual Survey of Manufactures: 1970 1971: (1973); Data on kilowatt-hour consumption based on U.S. Department of Commerce, 1972 Census of Manufactures, Fuels and Electric Energy Consumed, and U.S. Department of Commerce, Census of Manufactures: (1963).
Col. (4): Column (2) less Column (1).
Col. (5): Column (3) less Column (1).

FIGURE III

ANNUAL PERCENTAGE CHANGE IN ELECTRICITY
AND ENERGY SALES AND VALUE ADDED
FOR TWO-DIGIT INDUSTRIES, 1964 TO 1972

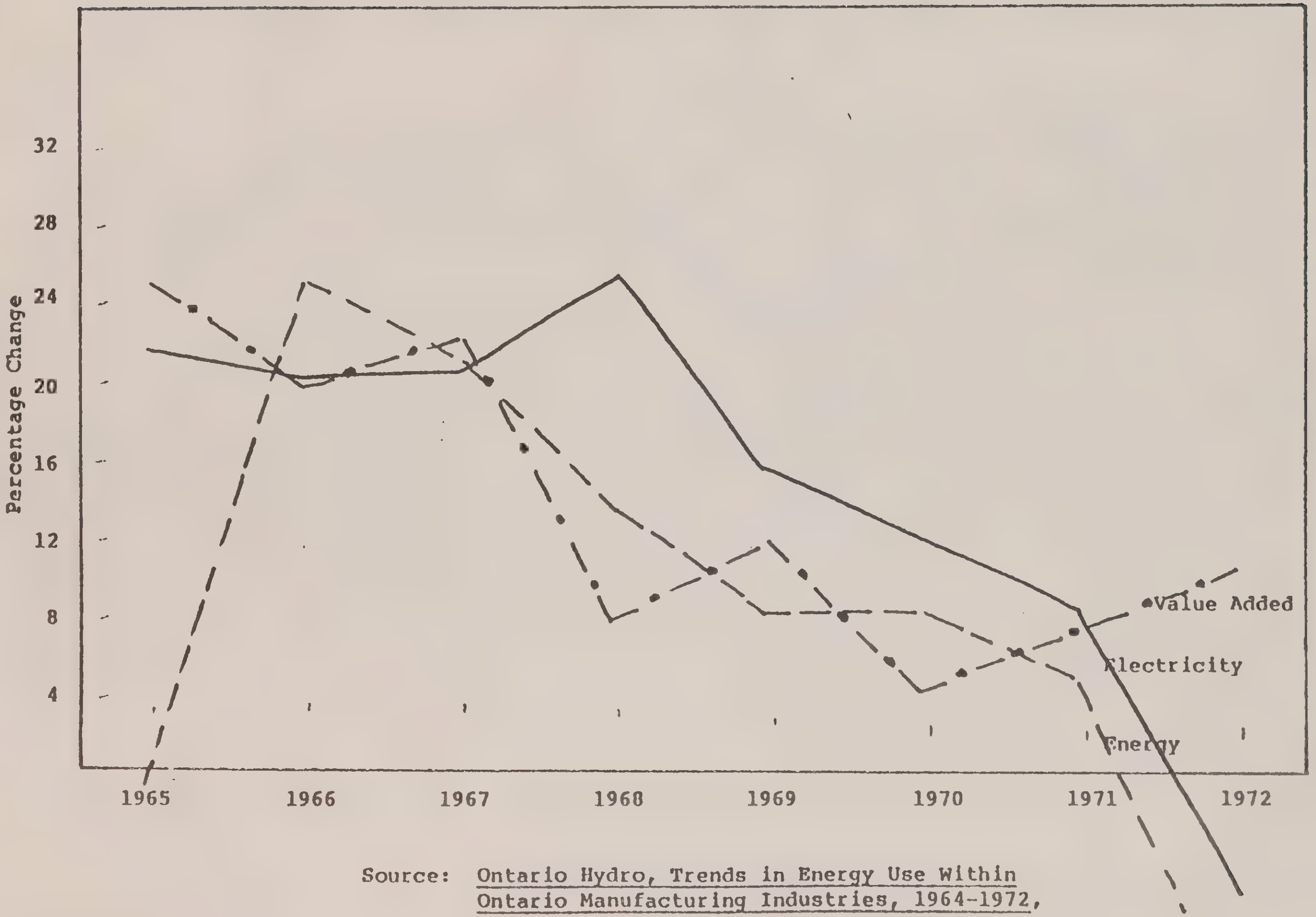
FOOD AND BEVERAGE PRODUCTS, SIC 10



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE III-2

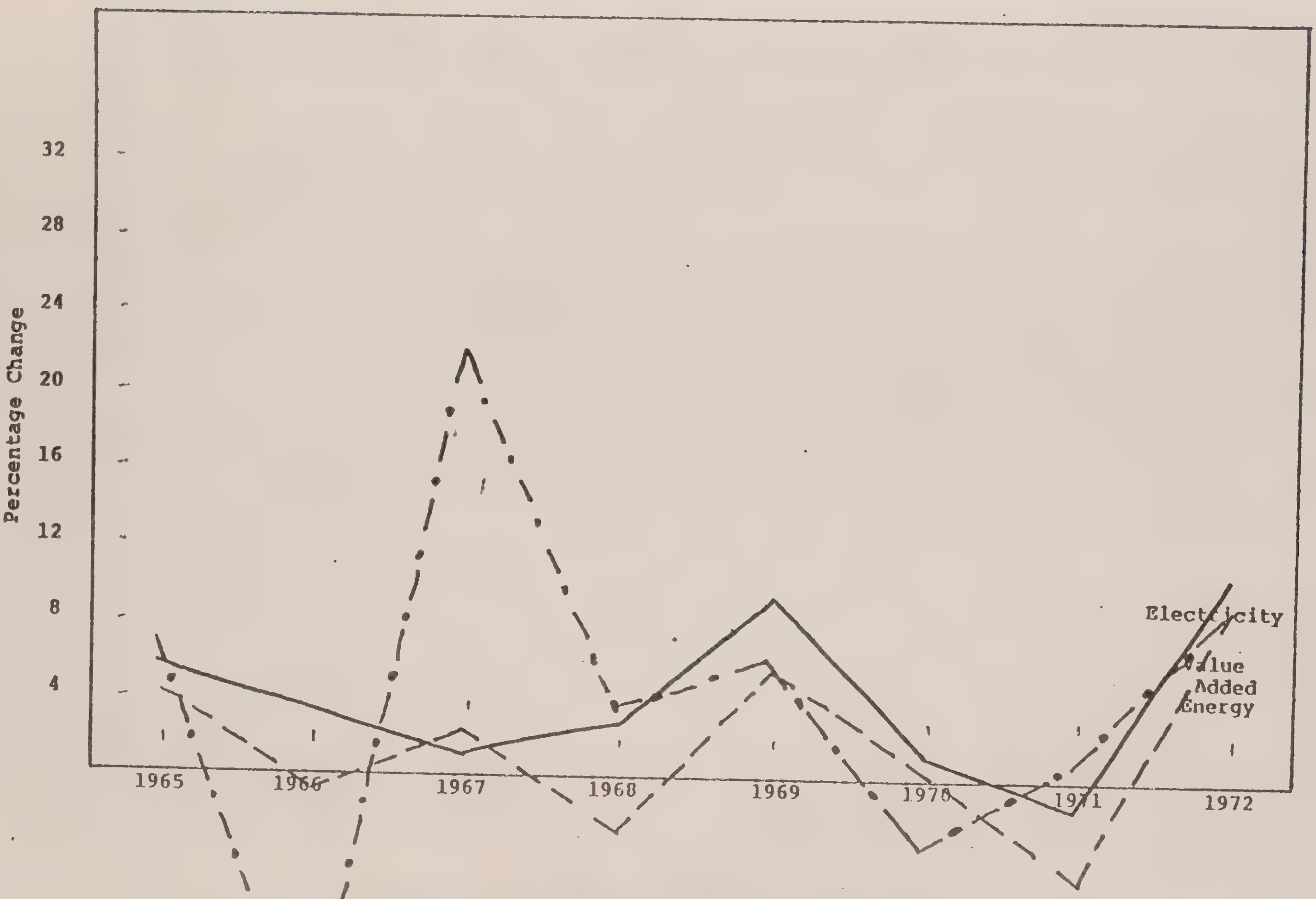
TOBACCO PRODUCTS, SIC 15



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE III-3

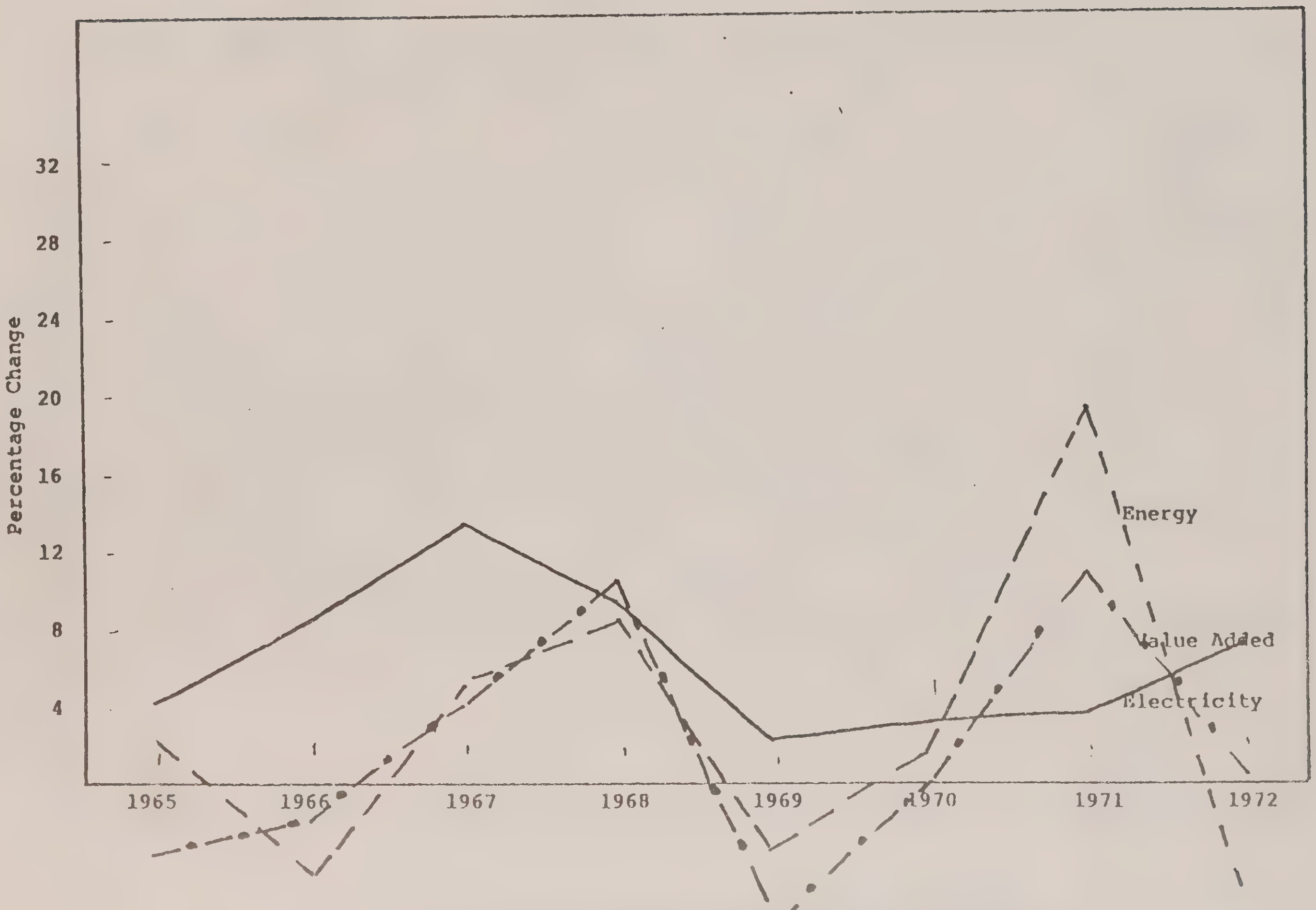
RUBBER AND PLASTICS PRODUCTS, SIC 16



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE III-4

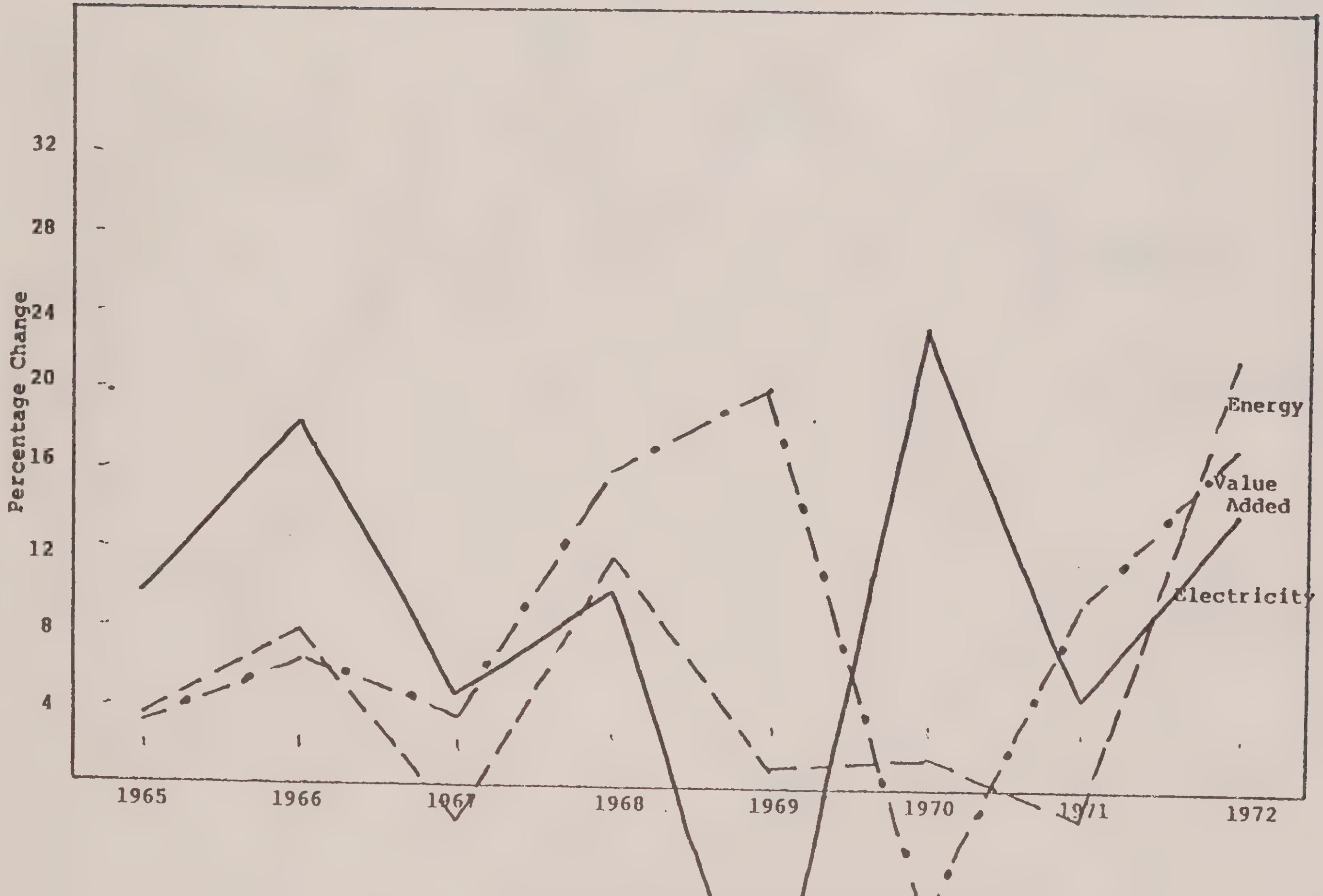
LEATHER PRODUCTS, SIC 17



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE III-5

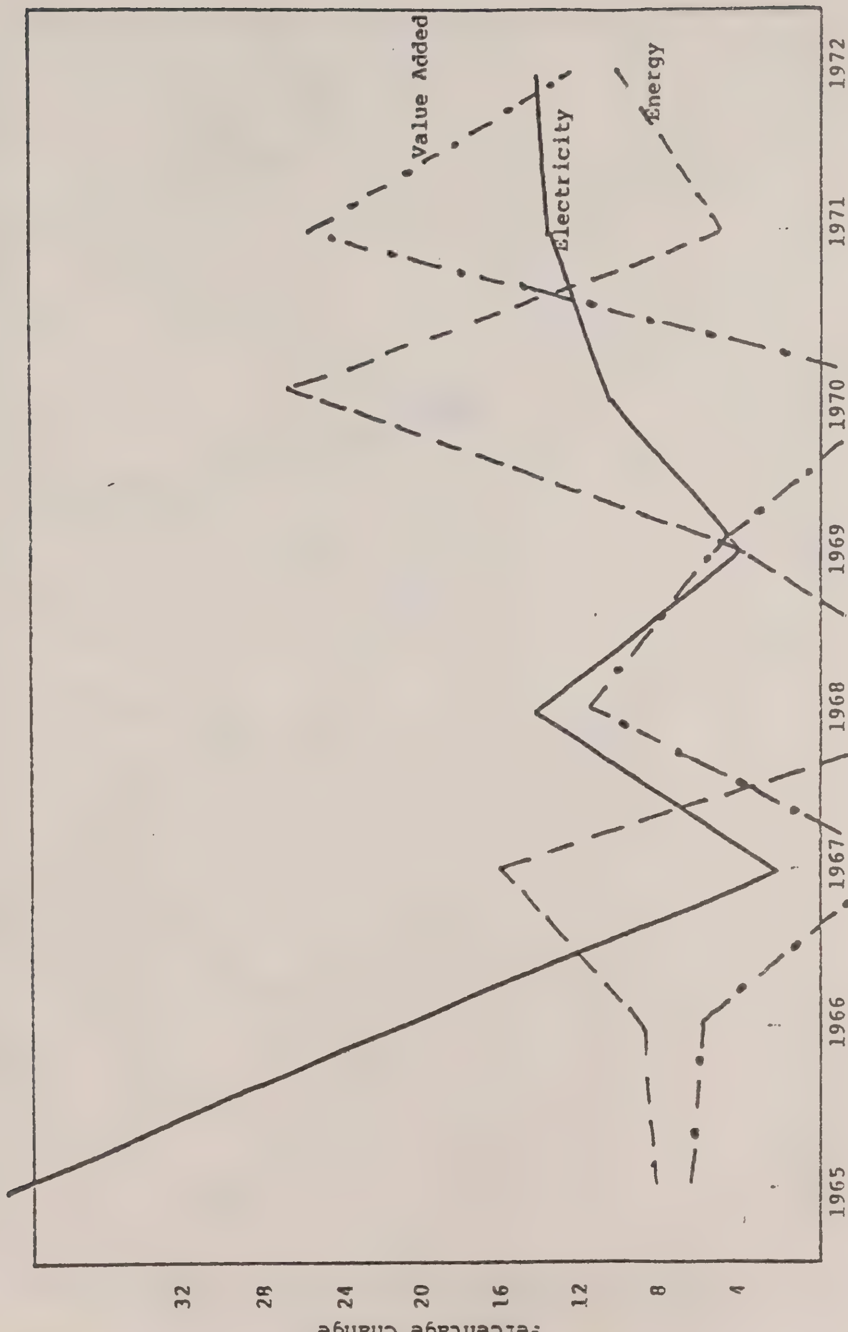
TEXTILE PRODUCTS, SIC 18



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE III-6

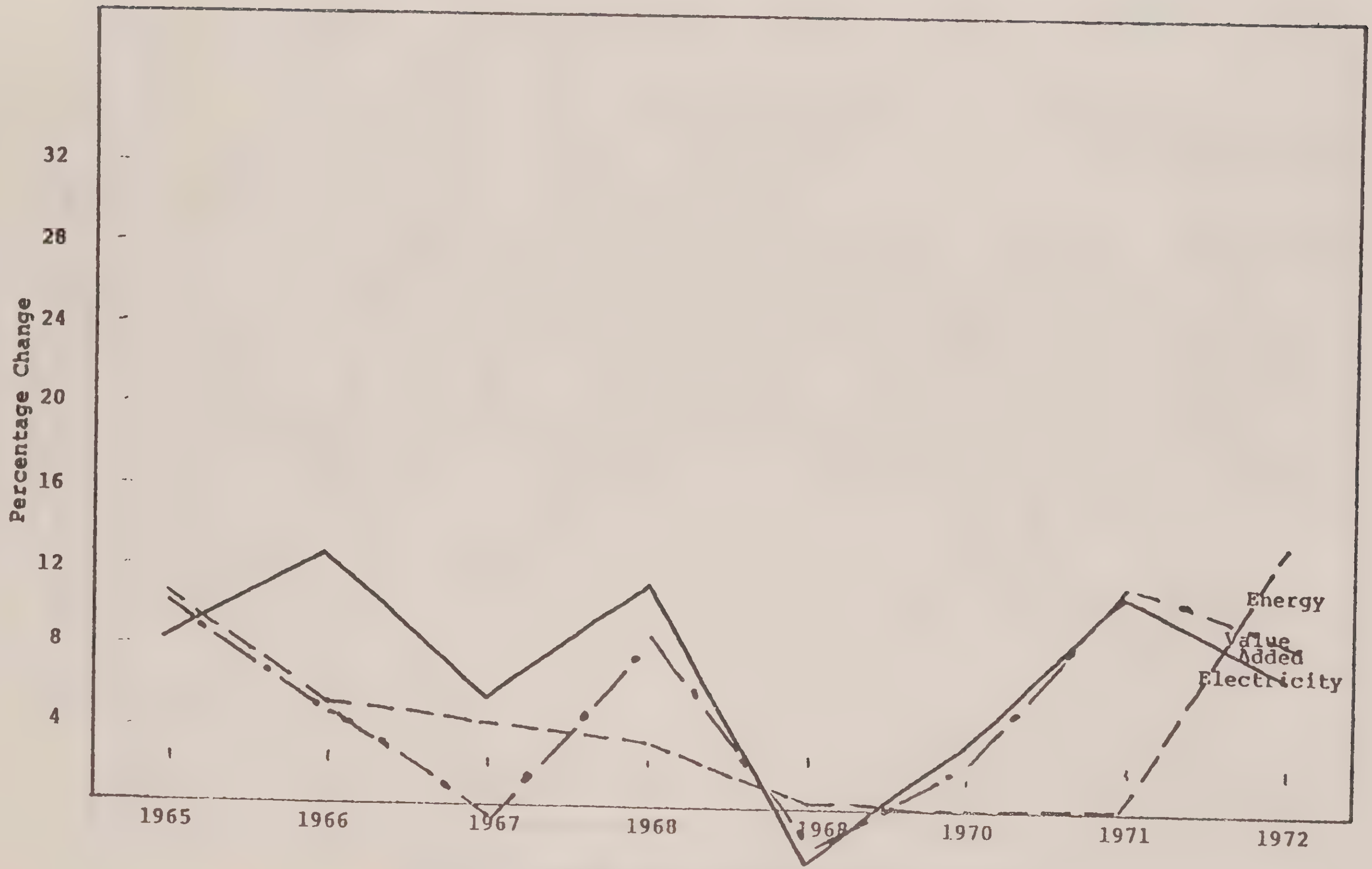
KNITTING PRODUCTS, SIC 23



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE III-7

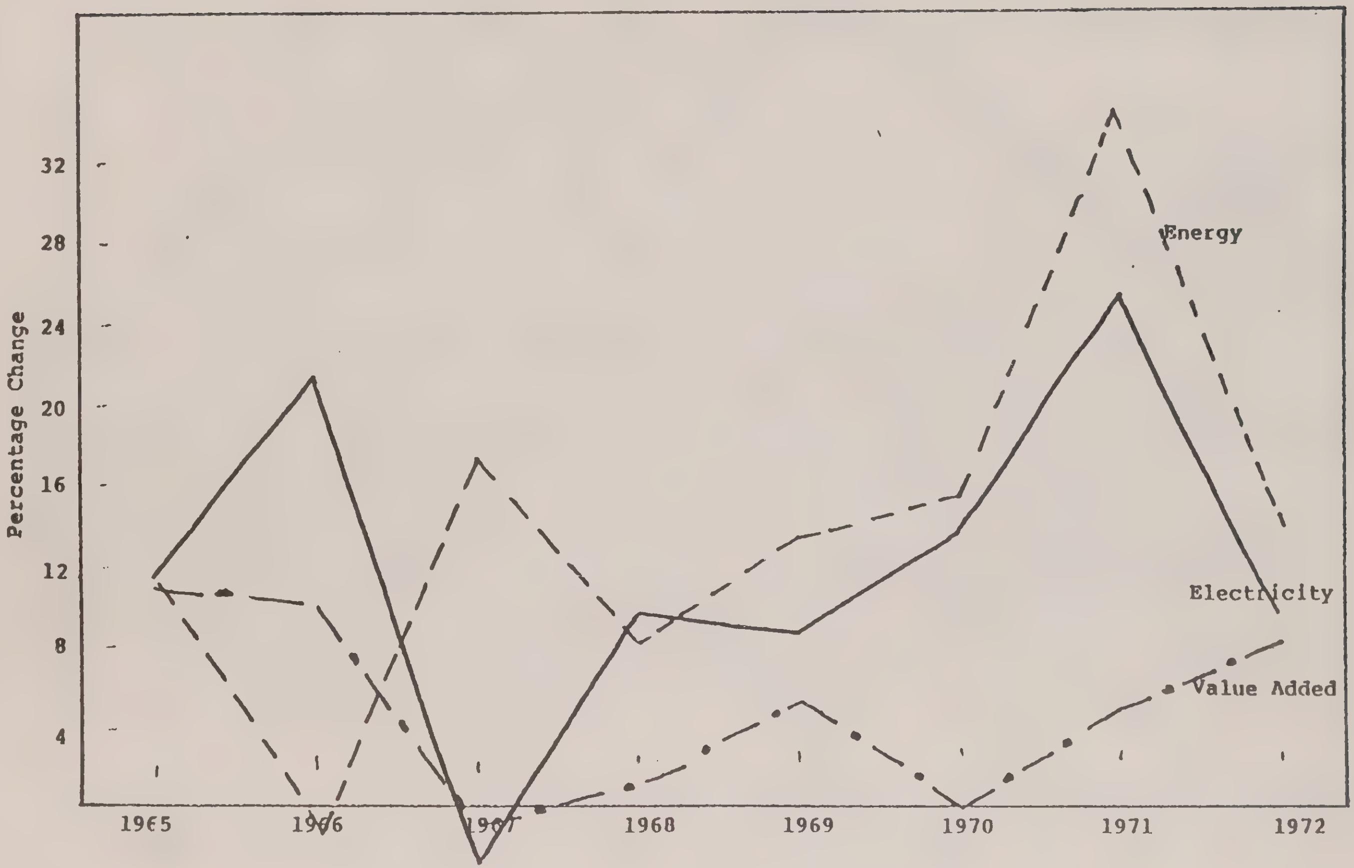
CLOTHING PRODUCTS, SIC 24



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE III-3

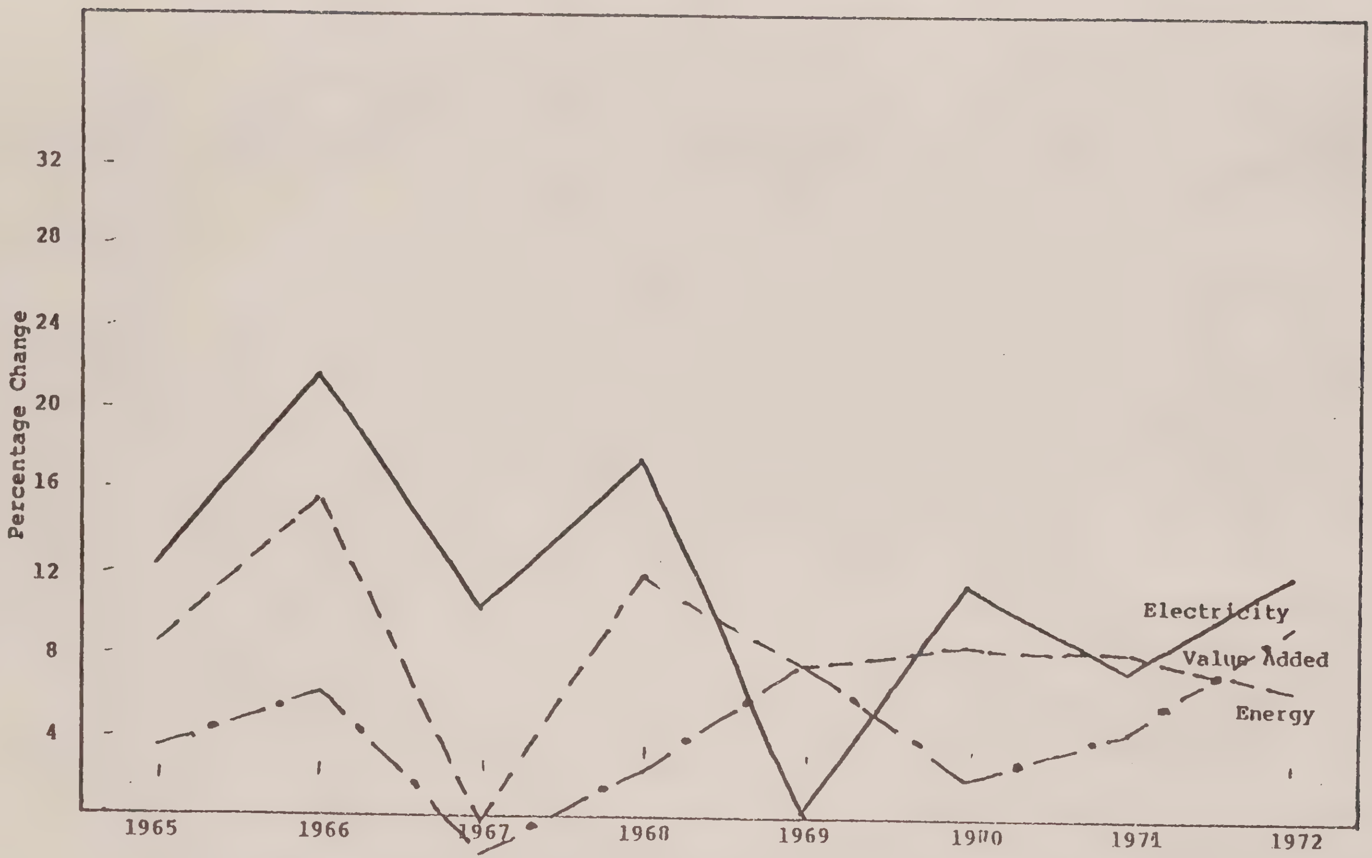
WOOD PRODUCTS, SIC 25



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

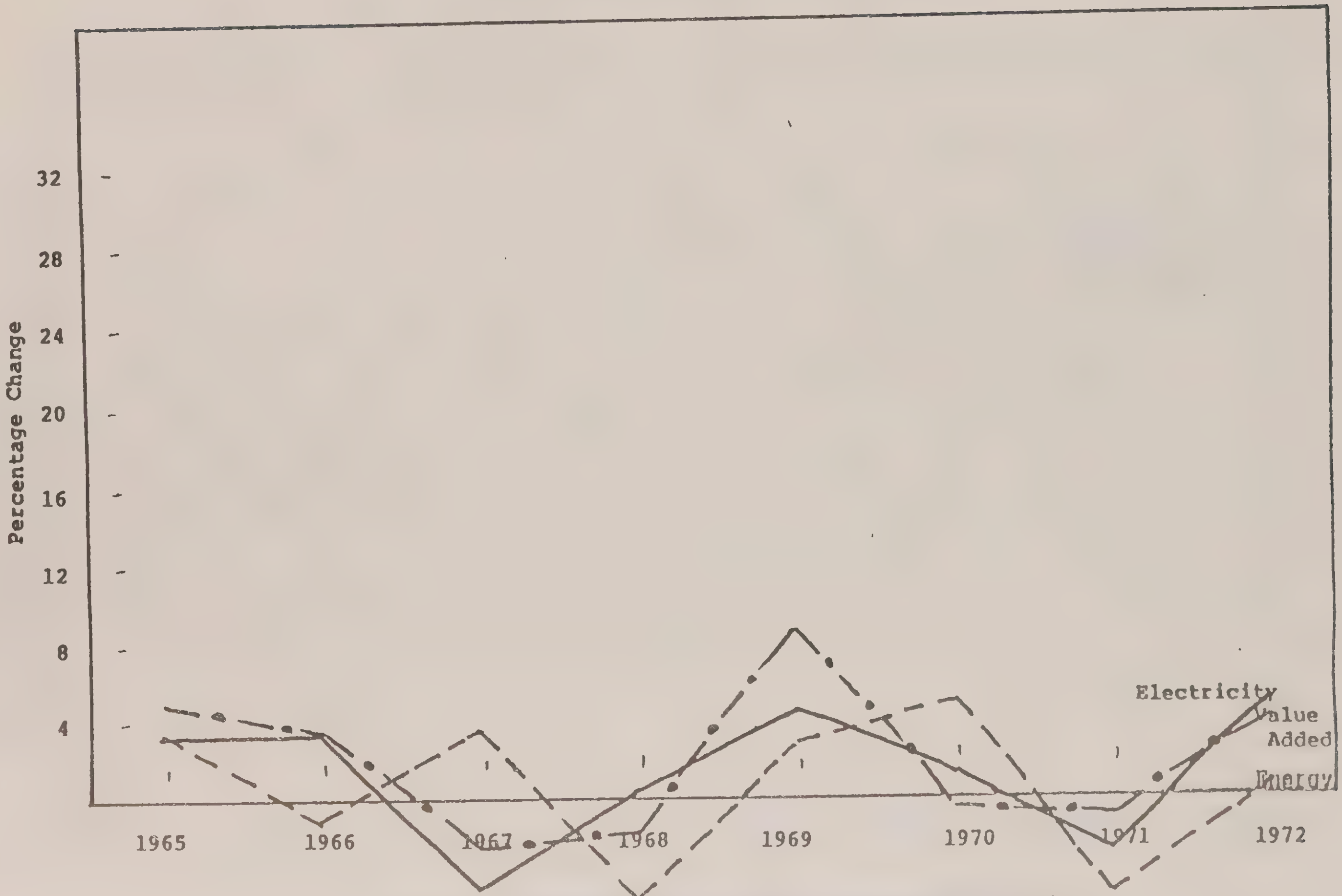
FIGURE III-9

FURNITURE AND FIXTURE PRODUCTS, SIC 26



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

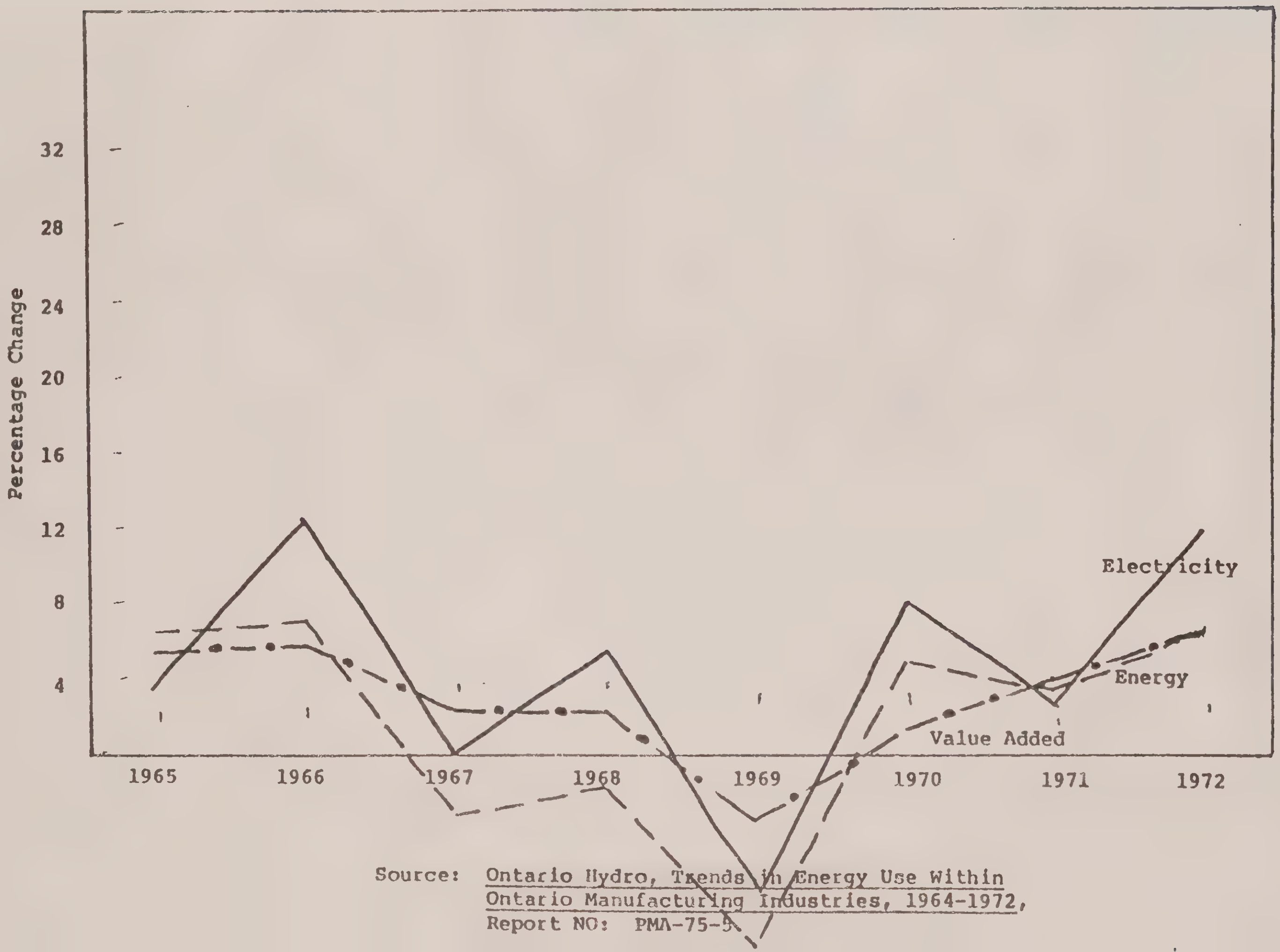
PAPER AND ALLIED PRODUCTS, SIC 27



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE III-11

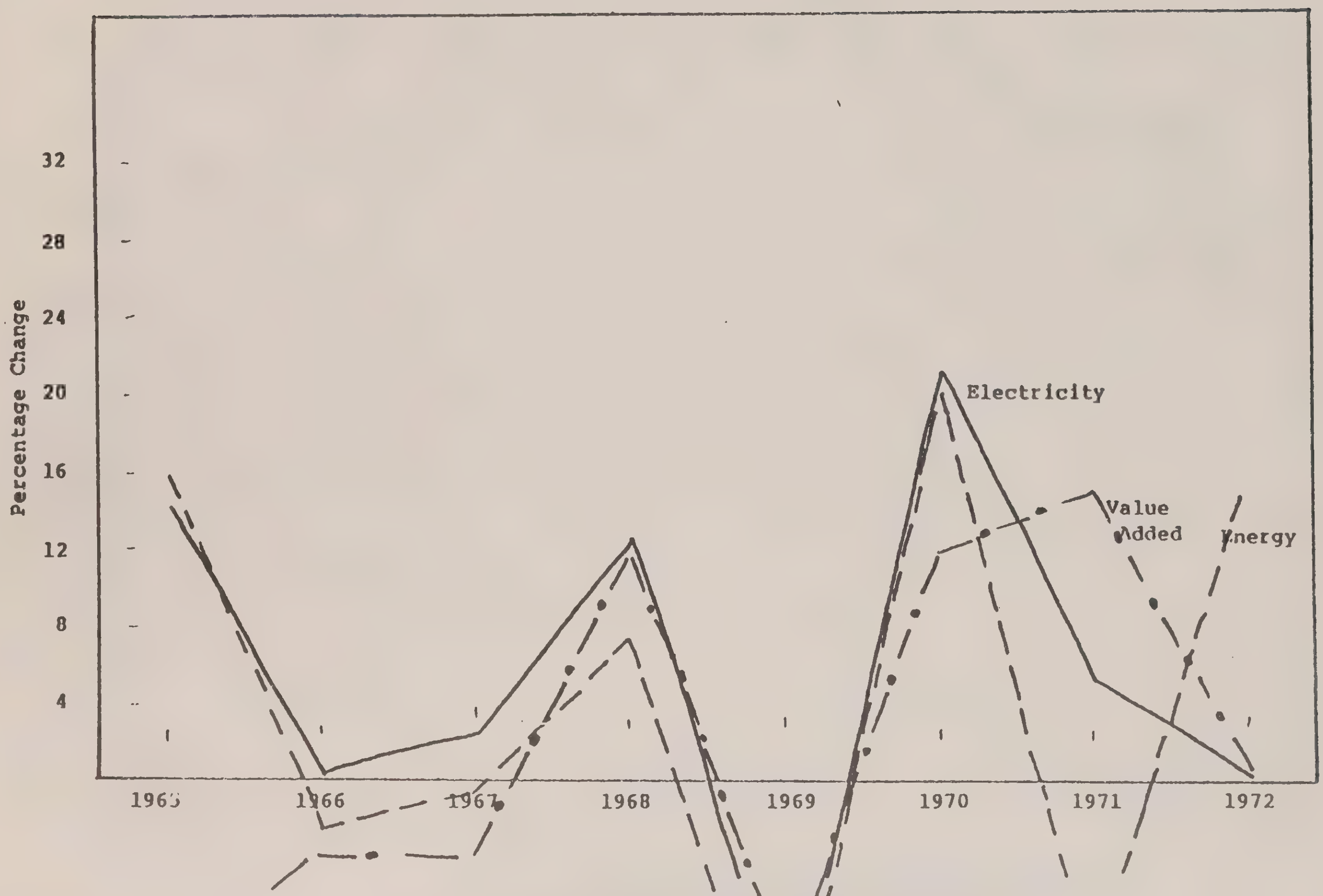
PRINTING AND PUBLISHING PRODUCTS, SIC 28



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5

FIGURE III-12

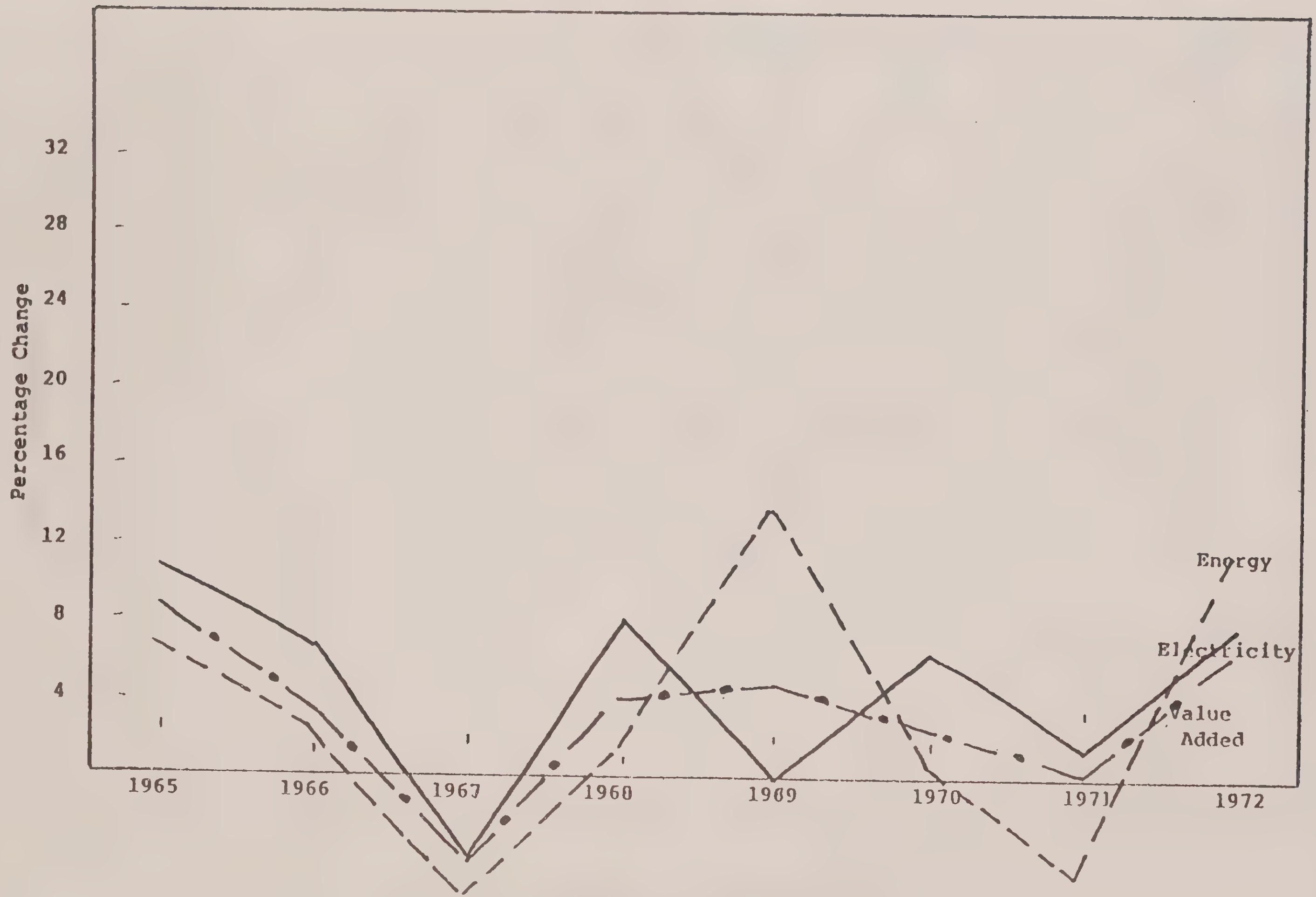
PRIMARY METAL PRODUCTS, SIC 29



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

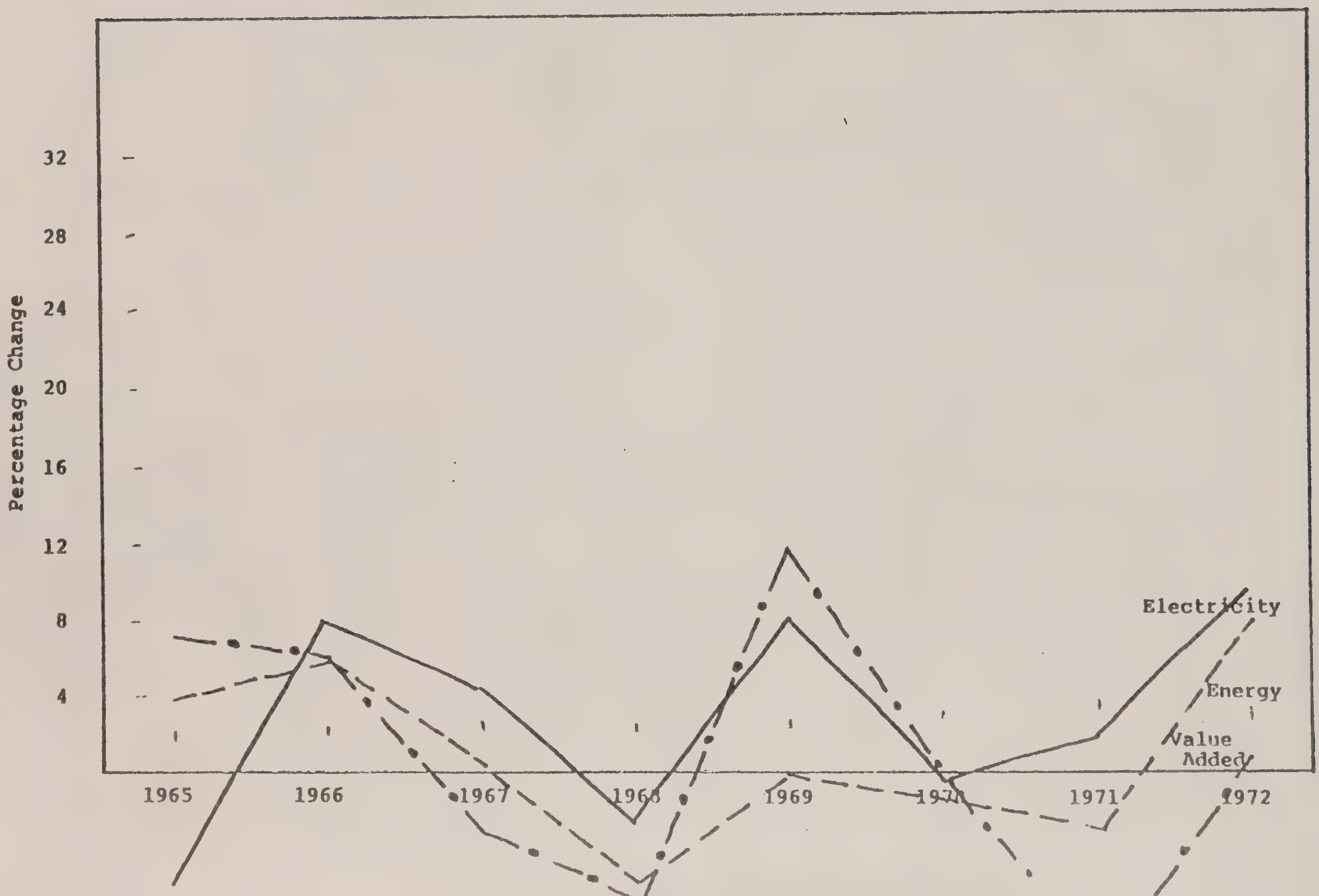
FIGURE III-13

METAL FABRICATING PRODUCTS, SIC 30



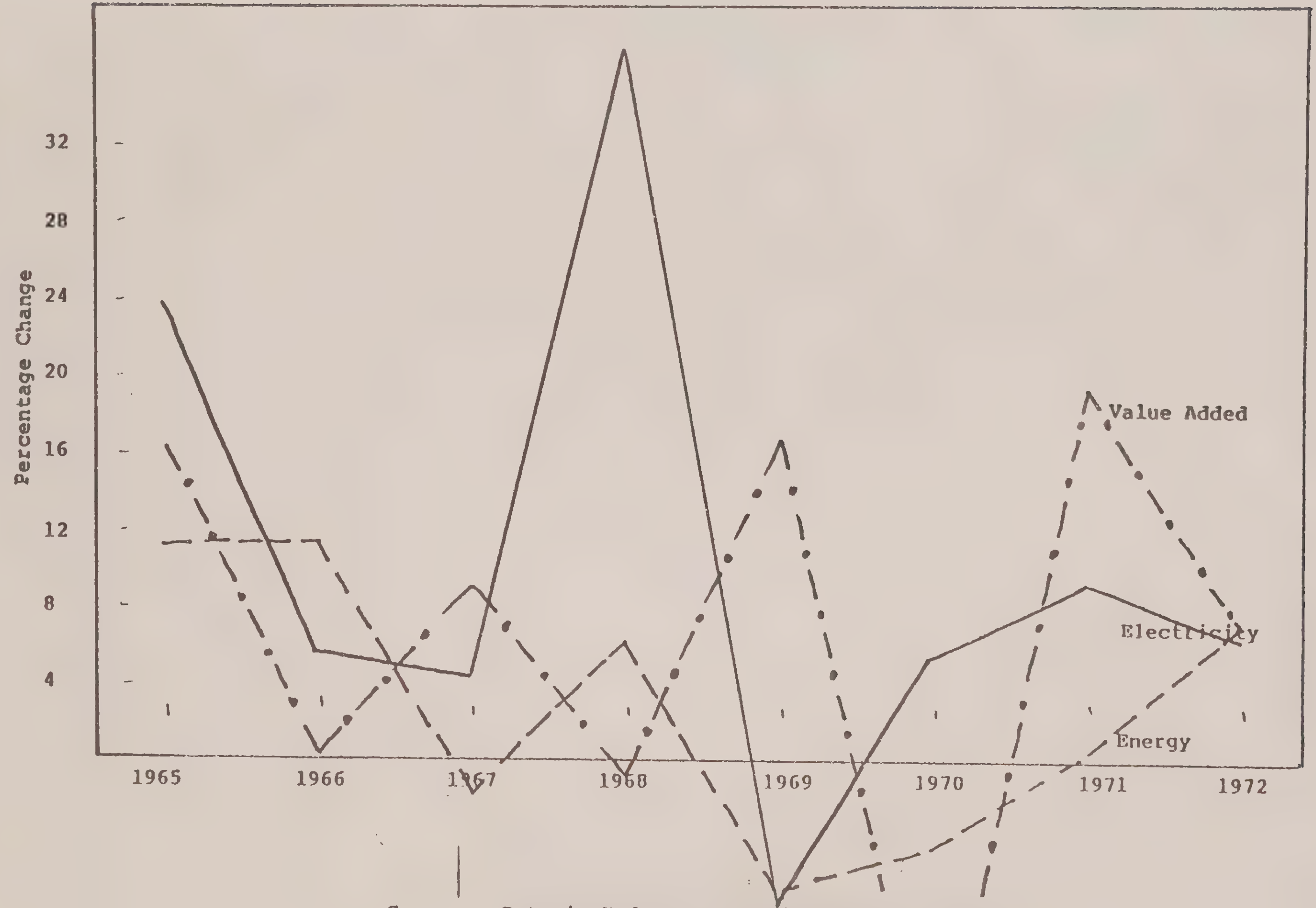
Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

MACHINERY PRODUCTS, SIC 31



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

TRANSPORTATION EQUIPMENT PRODUCTS, SIC 32

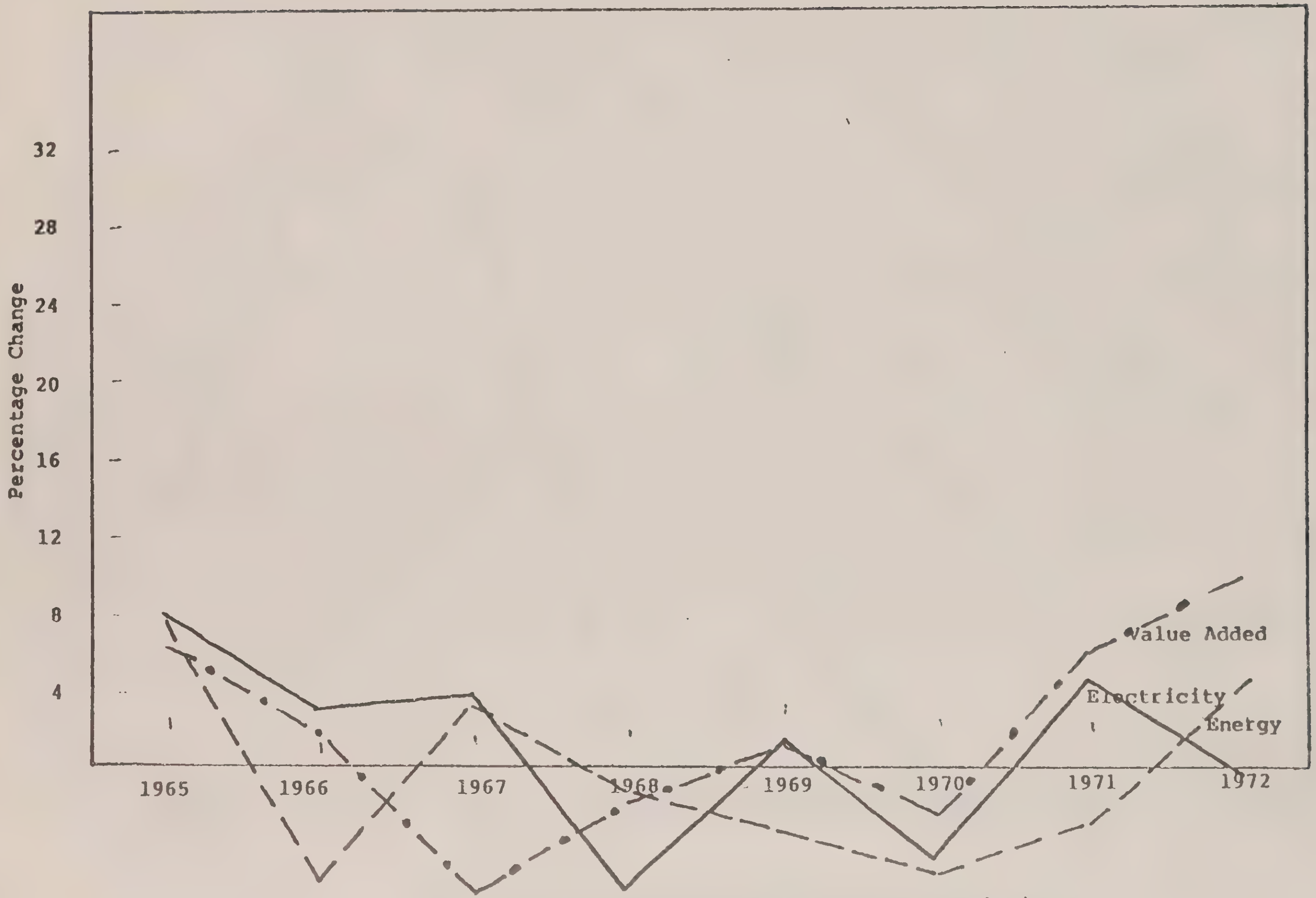


Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972,

FIGURE III-15

FIGURE III-16

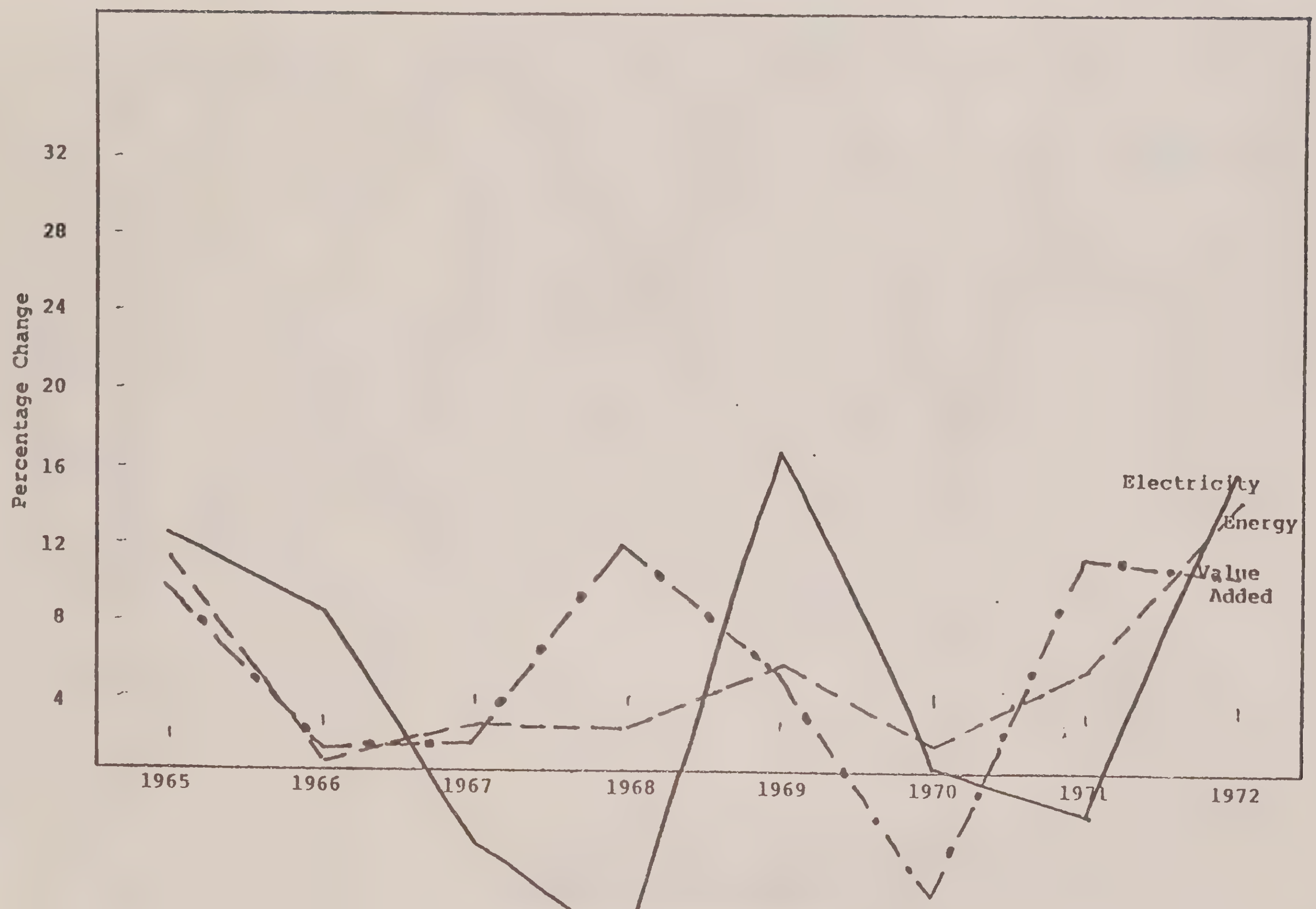
ELECTRICAL PRODUCTS, SIC 33



Source: <u>Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972</u>, Report NO: PMA-75-5.

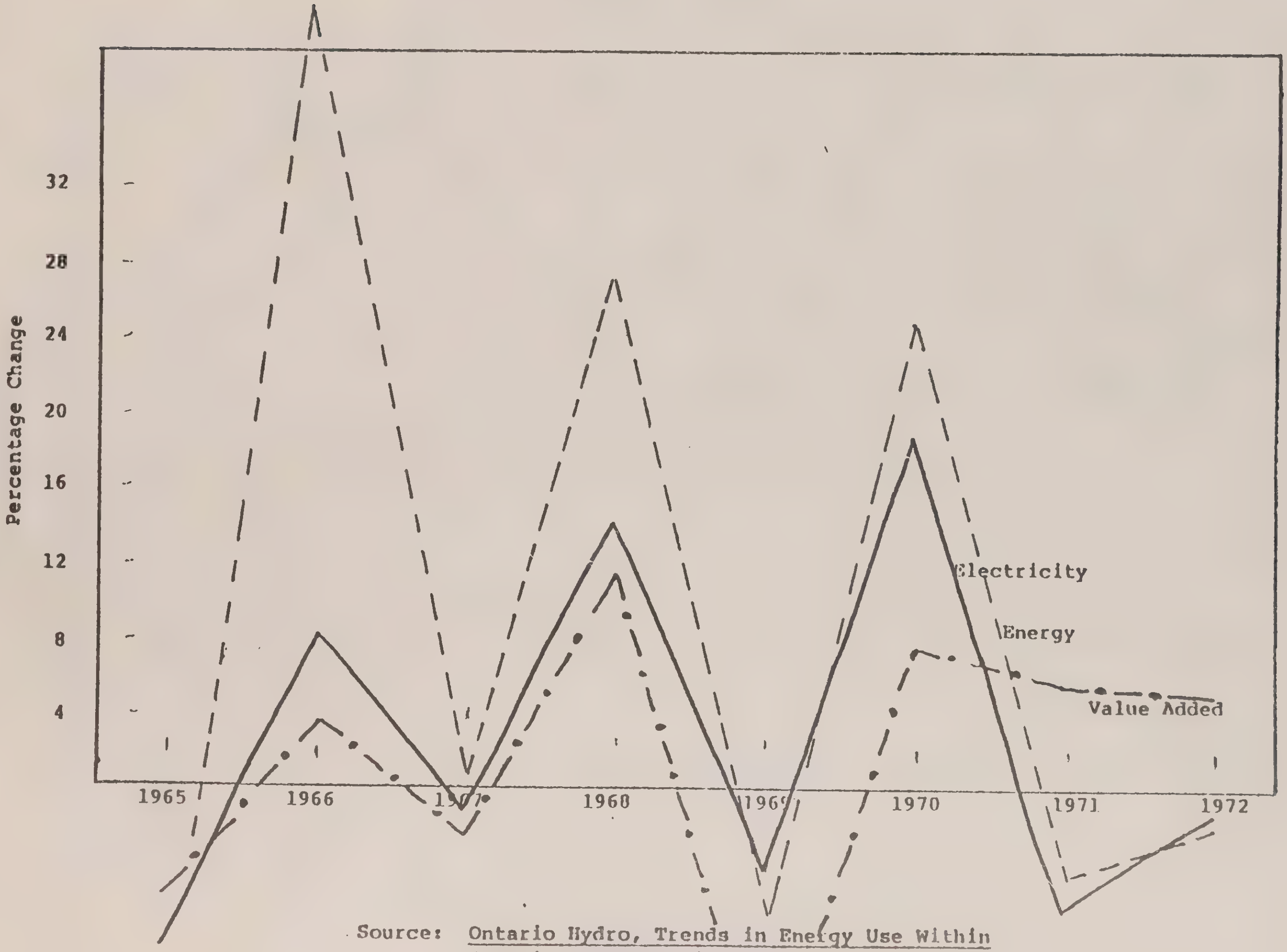
FIGURE III-17

NON-METALLIC MINERAL PRODUCTS, SIC 35



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972,

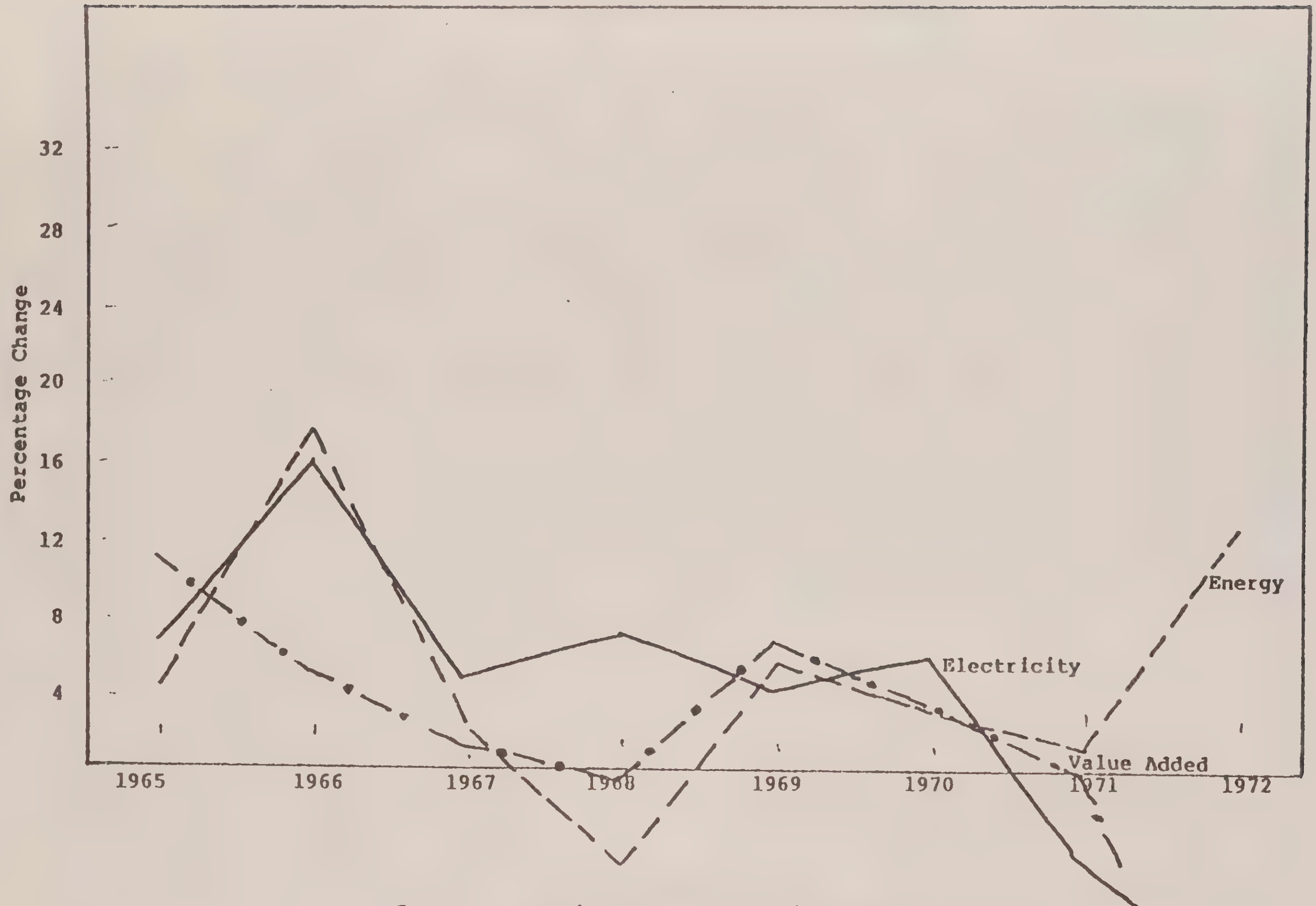
PETROLEUM AND COAL PRODUCTS, SIC 36



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE III-19

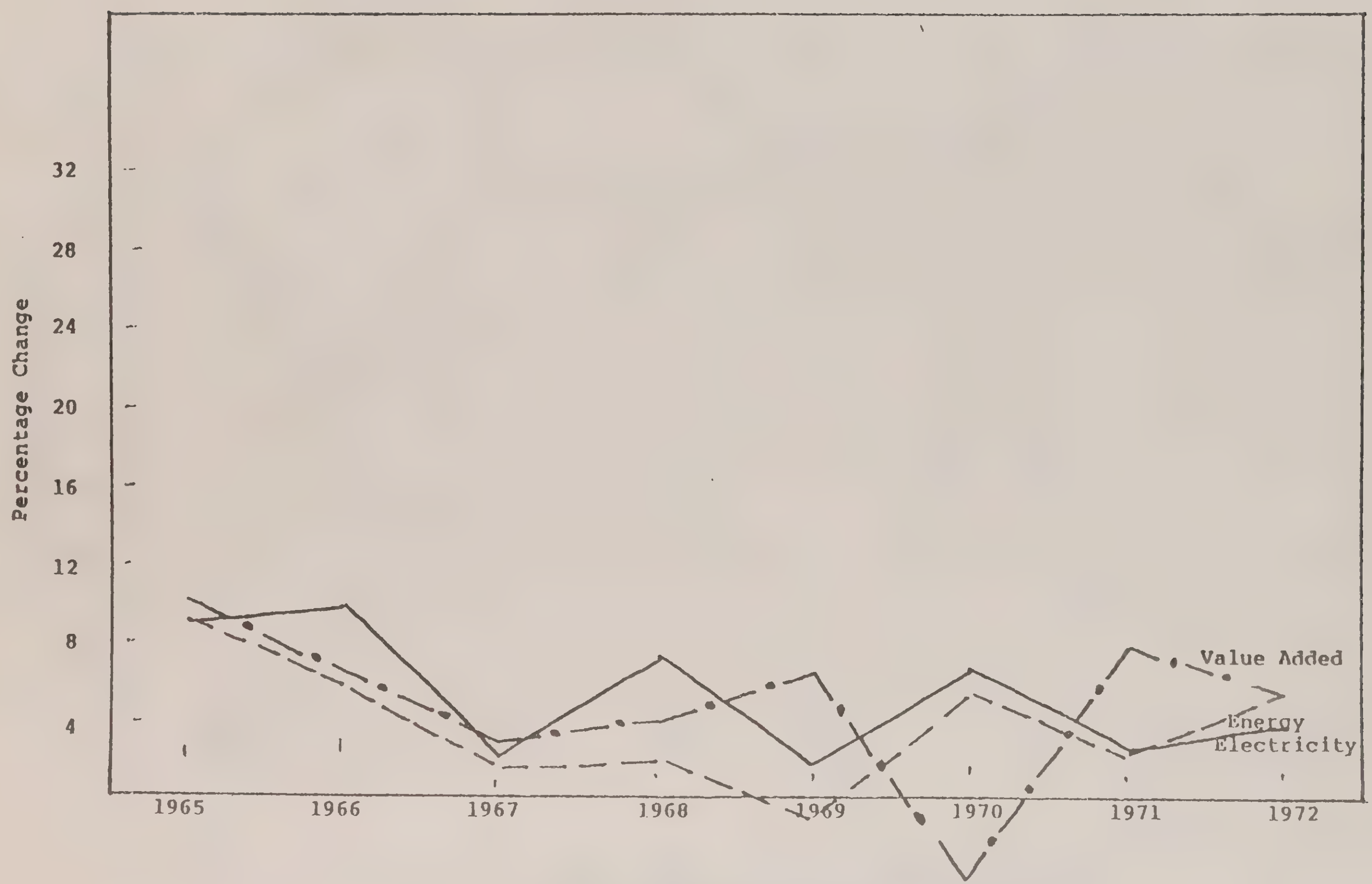
CHEMICAL AND CHEMICAL PRODUCTS, SIC 37



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE III-20

TOTAL MANUFACTURING



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

IV. SUBSTITUTION, COMPLEMENTARITY AND THE DEMAND FOR ENERGY

A. Problems in Interpreting the Results of the NERA Model as Applied to Canadian Data

The first problem we encounter in interpreting the long-run implications of the NERA model, as applied to Canadian data, relates to the fact that the derived elasticity and cross-elasticity coefficients apply to heterogeneous uses of electricity; they reflect unknown quantities of kilowatt-hours consumed for lighting and air conditioning as well as for more technological uses such as motor drive and process uses. It is possible that in the short run, higher electricity prices may encourage reductions in electricity consumption for such end uses as lighting or air conditioning, but it is unlikely that higher prices will encourage reductions in the amount of electricity directly consumed in the production of the final product. In the long run, we must also consider whether electricity and oil (or gas, coal, etc.) are viable substitutes for specific end uses. However, this is a relatively minor problem because the more energy-intensive industries use a major portion of electricity in industrial processes and the elasticities obtained from the NERA model would reflect the long-run adjustment to price changes for the technological uses of electricity.

The second problem we encounter relates to the inadequate treatment the model affords to the possibility

that other important inputs such as capital and/or labor may be either substitutes or complements for electricity or energy in production. The implications of research in this area are twofold: first, given that the demand for electricity or energy is in some degree affected by price and that, on the one hand, electricity or energy and capital and/or labor are complementary goods, a rise in the price of energy and/or electricity may be followed by a decrease in the demand for both electricity (energy) and capital (labor) and subsequently by a decrease in the level of output. If the case of complementarity between electricity (energy) and other inputs is present in all industries, this phenomenon could imply that economic growth will undergo a gradual slowdown. If, on the other hand, electricity (energy) and capital (labor) are substitute goods, the slack created by a decrease in the demand for electricity or energy can be taken up by either an increase in the demand for capital or an increase in the demand for labor. The ultimate effects on output and economic growth are not intuitively apparent in such a case. Second, even though the demand for electricity or energy is price reactive and complementary with respect to capital or labor, the same amount of electricity or energy as before can still be purchased if the added production costs can be passed along to the ultimate purchasers of the products. In other words, because such inputs as electricity, energy, capital, labor, etc. are intermediate inputs, the demand for them is derived

and, consequently, dependent not only on their relative prices but also on the demand for the final product. The more price elastic the latter, the more it will be affected by an increase in the price of a specific input.

B. A Review of Two Econometric Studies of Industrial Demand for Electricity

Having established the potential importance of ascertaining the degree of substitutability and complementarity among factors of production, we turn now to the results of two studies that provide evidence on these problems. The first study by Berndt and Wood focuses exclusively on the problem of substitution and complementarity while the second study by Fuss grapples with the problems of substitution and complementarity and of ultimate effects on final demand.

1. Berndt and Wood Study[1]

Berndt and Wood developed a model which consists of a translog production function where output is a function of capital, labor, energy and all other materials. From this production function, they derive a cost function where the total cost of producing a unit of output is dependent on the level of production and the prices of various inputs. The demand for a particular input is formulated as the cost

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[1] E. R. Berndt and D. O. Wood, "Technology, Prices and the Derived Demand for Energy," The Review of Economics and Statistics, Vol. LVII, August 1975, pp. 259-268.

share of that input as a function of the prices for each input. The price elasticities of demand for the various factors of production are defined in terms of cost shares and the partial elasticities of substitution between inputs.

Data for total U.S. manufacturing for the period 1947 to 1971 is the basis for the model. The energy quantity index is derived from interindustry flow tables and includes data on coal, crude petroleum, refined petroleum products, natural gas and electricity purchased by establishments.

The results obtained can be summarized as follows:

a. Energy demand is responsive to a change in the price of energy with elasticity approximately -0.47.

b. Energy and labor are substitutable with the cross-price elasticity of energy with respect to labor equaling -0.18.

c. Energy and capital show a degree of complementarity with cross-price elasticity of energy and capital at +0.18.

d. Capital and labor are found to be substitutable.

From these results, the authors conclude that because capital and energy inputs are complementary goods while labor and energy are substitute goods:

> ...the lifting of price ceilings on energy types would tend to reduce the energy and capital intensiveness of producing a given level of output and increase the labor intensiveness. Moreover, since investment

> tax credits and accelerated depreciation allowances reduce the price of capital services, (the complementarity finding) implies that these investment incentives generate an increased demand for capital and for energy. To the extent that energy conservation becomes a conscious policy goal, general investment incentives may become less attractive as fiscal stimulants.[2]

2. Fuss Study[3]

The Fuss study is essentially the same type of analysis as the Berndt and Wood study; it too utilizes a translog cost function derived from a production function and an input demand function defined from a cost function. There are, however, important differences between the two models.

Fuss uses an aggregation of Canadian industries, while Berndt and Wood use U.S. manufacturing establishments. There appear to be no a priori reasons, however, for the choice of sampled observations to affect the results significantly since industries in the two countries use the same basic technology. Furthermore, unlike Berndt and Wood who derive an energy price index, Fuss derives the cost of energy as a function of the cost of electricity, natural gas, coal, etc. This methodology enables him to analyze the

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[2] Ibid., p. 267.

[3] M. Fuss and L. Waverman, The Demand for Energy in Canada, confidential report for the Department of Energy, Mines and Resources, Institute for Policy Analysis, University of Toronto, Toronto, Canada, February 1975.

degree of substitution between the various fuels directly and the influence of price on the demand for an individual fuel. Fuss also uses the estimated price of energy as an instrumental variable in the final cost equation. This two-stage procedure further enables him to answer the questions:

a. What is the effect of a change in the price of a fuel (electricity, for example) on the cost of production?

b. What is the effect of a change in the price of a fuel on the demand for the service of labor or capital?

The empirical results reported are for total manufacturing using a combined time series cross-sectional sample of four regions (Quebec, Ontario, the Prairies, and British Columbia and Yukon) for the period 1961 to 1971.

For the total manufacturing model, it is found that the price elasticity for electricity for Ontario is approximately -0.43 with cross-elasticities varying between 0.21 for electricity and natural gas, and 0.75 for electricity and fuel oil. The degree of price elasticity for energy is found to be slightly lower for Ontario-- -0.36--with cross-elasticities between energy and capital of 0.0035 and between energy and labor of 0.034. Fuss concludes that his results confirm the presence of substantial interfuel substitution and a relatively low degree of substitution between energy and capital, and energy and labor. These latter results are in direct contradiction to the Berndt and Wood results that energy and labor are substitute goods but that energy

and capital are complementary goods. Based on our analysis of the trends in substitution among fuels within two-digit industries in Ontario,[4] the Fuss results which confirm substitution among the most important fuels seem most credible.

Fuss also uses his results to analyze the influence of a change in energy prices on the average cost of production. He finds that if the price of energy for total manufacturing were to double, average production costs would increase by approximately 1.5 percent. If the price were to triple, average production costs would rise by 5.0 to 8.5 percent. He thus concludes that substantial increases in the price of energy would exert little effect on production costs.

The total manufacturing elasticity estimates obtained from the Fuss model and from the Berndt and Wood model are not dissimilar--approximately -0.4 in both cases--despite the different data bases used. A major dissimilarity, however, lies in the fact that Fuss found some degree of substitution between energy and capital while Berndt and Wood found these two factors to be complementary. As already pointed out, the subject of whether substitution or complementarity exists between capital and energy is important because substitution may imply continued economic growth even if the price of energy continues to increase. On the

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[4] For a more complete discussion, see Appendix A.

other hand, complementarity between energy and capital leads to opposing consequences because an increase in the price of energy would tend to decrease the demand for both energy and capital with the possible consequence of slowing down the rate of production and economic growth.

A possible explanation for these conflicting results may be found in the data base used. While energy is often used <u>with</u> capital to replace labor, energy can also be <u>con-served</u> by increasing capital investment. For example, better insulation, more efficient motors, and computer control each involve additional capital investment aimed at saving energy. Thus, in many instances, gross complementary of capital and energy may coexist with some degree of substitutability. A refrigerator (capital) uses energy (electricity) to replace labor required. Without the refrigerator, more frequent purchasing--with related labor expense--would be required. In this situation, energy and capital are complements. However, it is also possible to reduce energy consumption in refrigeration by installing equipment with increased (and costly) insulation. Such modifications would be more advantageous in periods of rising energy costs, for example.

Consequently, it may not be so surprising that the Berndt and Wood study, which uses data going back to 1947, finds capital and energy to be complementary, while the Fuss study, using data going back to 1961 (and also cross-sectional data), finds them to be slightly substitutable.

While it may be valid to infer that energy and capital will tend to be more like substitutes in the immediate future, a sweeping generalization to this effect must be interpreted with caution.

Whatever the case, the results obtained from the two studies briefly reviewed in this section must be considered with a degree of caution for two reasons in particular. First, in relation to the formulation of the demand for a factor of production equation, the derivation of the demand equation is such that the dependent variable is the cost share of the input in the total cost of producing the output. The cross-elasticity coefficient between two factors, energy and capital for example, thus depends on the value of the regression coefficient of capital in the energy demand equation and on the product of the cost shares of capital and the cross-elasticity coefficient between capital and energy. A problem arises because, for a given value of the regression coefficient, cross-elasticity will be higher the greater the disparity in cost share between two factors; similarly, price elasticity will be lower, the greater the disparity in cost shares between two factors. This implies that if a factor has come to play an important role in the production process, i.e., total cost outlays on that input are large in relation to other inputs, it will have a lower elasticity coefficient. Therefore, the estimated elasticity is valid only for the sample selected and forecasts based on

such elasticity estimates are bound to be misleading because as prices of inputs change, demand for factors may change. This phenomenon would alter the cost shares and eventually suggest different elasticities from those originally obtained. The following discussion is illustrative of this point.

If an energy-intensive industry spends a large percentage of its total cost of production on energy, the price elasticity of energy will be low. One must bear in mind, however, that high energy cost shares may have been due to cheap energy prices during the period under study in the first place. If energy prices are altered drastically and the cost share for energy decreases, its price elasticity should increase. Thus, estimated price elasticities cannot be considered reliable guides for policy decisions.

A second and more serious flaw present in both studies is the aggregation of all industries under the general heading of total manufacturing. With the exception of the Fuss analysis of the food and chemical industries at the two-digit level, both studies are predicated on the assumption that all industries can be treated as one. It should be obvious, however, that even at the two-digit level, industries cannot be compared because such factors as technology and mix of inputs vary substantially among them. At the risk of belaboring the obvious, Figures A-1 through A-19 of Appendix A illustrate that the mix of energy components for

industries within Ontario Hydro's service territory diverged markedly over the period 1964 to 1972. Similar trends could probably be observed for such other factors of production as capital, labor and raw materials. Finally, even Fuss' attempt to disaggregate is open to criticism along these lines because, as already noted, two-digit level analysis does not take account of important differences among component subindustries. Treating separate industries such as food and chemicals (as in the Fuss study) at the two-digit level without taking into account the role of subindustries also introduces a bias in the results.

The problem with an aggregated analysis of all industries or even with a two-digit level analysis is that such procedures fail to take into account the composition of products endemic to each industry. We pointed out, in Section III, that subindustries tend to vary in terms of their electricity intensiveness; and that subindustries which use more electricity per dollar of value added tend to locate in areas where electricity is inexpensive. Price elasticity estimates from studies that are based upon aggregated data or that have not considered the location effect are biased and cannot provide reliable guidelines for policy analysis.

On the positive side, the two studies reviewed in this section are nevertheless the best of their kind from a methodological point of view. The selection of a translog function in both studies must be highly commended as well

as the separate treatment of energy and its components as inputs alongside with capital, labor and other raw materials. It is evident that energy can exert a significant influence on both the level and rate of growth of production (as evidenced in the U.S. by recent industrial curtailments of natural gas). In the short and intermediate run, shortages of energy components are more efficacious than increases in the price of such components because the effect of price increases very much depends on whether additional energy costs can be passed along to buyers of the products and whether energy is a substitutable or a complementary good vis-a-vis other factors of production.

When and if the methodologies of the two studies considered are applied to a more detailed sample of industries, estimates of price responsiveness and of the degree of substitution and complementarity among factors of production should clarify our understanding of the issues involved. The benefits to be gained from such clarification are, of course, invaluable to those faced with the onerous task of formulating future energy policies.

C. Summary of Results and Conclusions

Both the objectives and conclusions of this study have been discussed in Section I. We will briefly recapitulate them here.

This study was undertaken primarily to determine whether patterns of industrial demand for electricity within

Ontario during the period 1964 to 1972 suggest price elasticities consistent with those estimated by NERA using United States data. The method we use to make that determination is to apply the elasticities estimated using U.S. industrial data to similarly defined Ontario industrial data. We conclude that the Ontario data do suggest very similar underlying price elasticity values, though it is possible that the -0.5 estimate of overall industrial price elasticity may be a slight overestimation of the actual value. Consequently, it is our opinion that the results obtained can be used by Ontario Hydro for purposes of ascertaining the effect on industrial demand for electricity of electricity price changes.

Another objective of this study was to review the recent models of industrial demand for electricity done by Berndt and Wood and by Fuss. Both of these studies incorporate variables which have been omitted from most of the econometric models (including the NERA model) to date and which we feel should be included in a complete model (Section II). While we conclude that the results obtained in these two studies are certainly not definitive (in some cases, the results of the two studies contradict one another), we feel that both studies are important contributions toward developing a complete model of industrial demand for electricity. In particular, the incorporation of energy as an input in the production function, along with capital and labor, is, in our opinion, a significant contribution to the task under consideration.

In view of the fact that the NERA model underpredicts (in the statistical sense) growth in industrial demand for electricity in Ontario Hydro's serivce area over the period of analysis, we conclude that further research along the lines developed in Section II (and attempted by Berndt and Wood and by Fuss) is required to capture fully the effects of all causative variables on industrial demand for electricity.

Consequently, as stated in Section I of this study, our recommmendations to Ontario Hydro are: (1) to consider the NERA estimate of electricity price elasticity with respect to industrial demand as applicable to Ontario Hydro's service area; and (2) to pursue further research in the area of forecasting changes in industrial demand for electricity, incorporating those factors discussed in Sections II and IV of this study.

THE ROLE OF ELECTRICITY WITHIN ONTARIO HYDRO'S INDUSTRIAL SECTOR: AN ANALYSIS OF TRENDS

Throughout the period 1964 to 1972, electrical energy sales to the industrial sector accounted for over 30.0 percent of total Ontario Hydro sales. Table A-1 shows that a high of 40.8 percent was reached in 1966, followed by a steady decline to a low of 32.7 percent in 1972. During that same period, total electrical energy sales grew at an annual rate of 7.6 percent while sales to the industrial sector increased at an annual rate of 5.0 percent. The largest single yearly increase in sales to industrial users occurred between 1965 and 1966 when the rate of growth was 9.9 percent.

Tables A-2a and A-2b reveal that three industries (Primary Metals [SIC 29], Paper and Allied Products [SIC 27] and Chemicals and Chemical Products [SIC 37]) have consistently accounted for over 60.0 percent of the total industrial electrical energy sales of Ontario Hydro. Primary Metals has been the largest customer with over 22.0 percent of industrial electricity consumption. The share of consumption accounted for by the Paper and Allied Products industry declined gradually from a high of 22.4 percent in 1964 to a low of 18.0 percent in 1971. The Chemicals and Chemical Products industry's share of consumption peaked in 1969 at a value of 18.0 percent but decreased rapidly thereafter. In general, the industrial sector increased its consumption

of electrical energy by approximately 5.0 percent per year between 1964 and 1972. However, during that same time period, three other industries (Transportation Equipment [SIC 32], Tobacco Products [SIC 15] and the Furniture and Fixture industry [SIC 26]) had yearly rates of increase in consumption of 10.0 percent or greater.

The growth in industrial demand for electricity within the Province of Ontario during the period under study was accompanied by a significant increase in the demand for total energy (Table A-3). We find that total energy consumption increased at an annual rate of 3.2 percent, as compared to a 5.0 percent increase for electricity alone. Moreover, electricity as a percentage of total energy consumed increased from 16.2 percent in 1964 to 18.4 percent in 1970 and to 18.0 percent in 1972.

These aggregate figures, though useful in themselves, fail to reveal interindustry differences. Tables A-4a, A-4b and A-5 indicate that the Primary Metals (SIC 29), Paper and Allied Products (SIC 27) and Chemicals and Chemical Products (SIC 37) industries are not only the largest consumers of electricity but also of total energy. These three industries, combined, accounted for over 55.0 percent of the total energy consumed by industries in Ontario in 1972. Among the fastest growing users of energy, the Petroleum and Coal Products (SIC 36), Wood (SIC 25), and Furniture and Fixtures (SIC 26) industries may be singled out.

Analysis of energy demand for the average establishment (Table A-5) reveals that plants of the Primary Metals (SIC 29) and Paper and Allied Products (SIC 27) industries are the highest average users of energy. Other industries, though relatively small users of energy in absolute terms, also reveal high average use (e.g., Petroleum and Coal Products [SIC 36], Tobacco Products [SIC 15] and Wood [SIC 25]).

With respect to substitution among fuels used by two-digit industries, analysis of historical trends reveals the following pertinent trends:[1]

a. By 1972, coal accounted for less than 10.0 percent of total energy consumed in all but two industries, to wit, Primary Metals (SIC 29) and Transportation Equipment (SIC 32). This result is particularly striking because, in 1964, coal was the most important source of energy in seven industries and the second most important source in an additional six industries. By 1970, though, coal's share had declined to less than 5.0 percent in 12 industries.

b. The share of electricity has been increasing in all but four industries.[2]

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[1] See Figures A-1 through A-20.

[2] It must be pointed out, however, that the rate at which electricity has been gaining ground has been relatively slow.

c. Utility gas has increased its share at a rather fast pace since the 1968 to 1969 period. By 1972, it was the most important fuel in 14 of 19 industries, accounting for over 40.0 percent of total energy consumed in 12 industries.

d. The share of fuel oil has been declining steadily in most industries since 1968, and was lower in 1972 than it was in 1964 in 12 of the 19 industries.

It is difficult to draw definitive conclusions from this analysis because data by end uses are not provided. For example, we know that a large percentage of coal, oil and natural gas is used for space heating purposes while electricity is mainly used for lighting and technologically related uses. Figures A-1 through A-19 clearly show that there has been substitution between utility gas, oil and coal. The use of electricity has also increased but to a lesser extent than that of the other competing fuels. What these graphs do not show, however, is whether there has been any significant substitution between electricity and other fuels for industrial processes or technologically oriented uses.

Given the kind of data available, we can, however, determine whether individual industries are becoming more energy intensive and/or more electric intensive. As can be seen in Figures B-1 through B-20, of the 19 two-digit industries studied, only eight were more energy intensive but 15

were more electric intensive in 1972 than they were in 1964. Of the 11 industries that have decreased their energy consumption per dollar of value added, eight have shown an increase in the amount of electricity consumed per dollar of value added. All eight industries that have shown an increasing degree of energy intensiveness have also shown an increasing in their use of electricity.

TOTAL KILOWATT HOUR SALES TO ONTARIO HYDRO'S INDUSTRIAL USERS

1964 - 1972

	Total Electrical Energy Sold by Ontario Hydro	Total Electrical Energy Sold to All Ontario Hydro Industrial Users	Percent (2)x100÷(1)
	--------(Millions of Kwh)--------		
	(1)	(2)	(3)
1964	41,115	16,307	39.7
1965	44,213	17,777	40.2
1966	47,944	19,541	40.8
1967	50,725	19,941	39.3
1968	54,816	21,353	39.0
1969	58,413	21,671	37.1
1970	63,815	23,084	36.2
1971	67,817	23,638	34.9
1972	75,036	24,513	32.7
Annual Rate of Growth	7.6%	5.0%	

Source: Col. (1): Ontario Hydro, Statistical Yearbook, Supplement to the Sixty-Sixth Annual Report for the year 1973, pp. 2-3.
Col. (2): Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NC: PMA-75-5, p. A101.

TABLE A-2a

TOTAL KILOWATT-HOUR SALES TO ONTARIO HYDRO'S INDUSTRIAL USERS BY TWO-DIGIT INDUSTRIES[1]

1964 - 1972

SIC Code	Industry	1964	1965	1966	1967	1968	1969	1970	1971	1972	Annual Rate of Growth
		(Millions of Kilowatt-Hours)									(Percent)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
29	Primary Metal	3,729	4,270	4,416	4,610	5,024	4,529	5,385	5,455	5,673	4.8%
27	Paper and Allied	3,659	3,756	4,056	3,926	4,054	4,286	4,215	4,243	4,592	2.4
37	Chemical and Chemical Products	2,587	2,779	3,331	3,447	3,806	3,891	4,135	3,995	3,618	5.1
35	Non-Metallic Mineral Products	1,387	1,543	1,708	1,552	1,594	1,678	1,725	1,703	1,908	2.8
32	Transportation	809	1,018	1,120	1,219	1,418	1,572	1,506	1,766	1,892	10.3
10	Food and Beverage	868	927	962	1,026	1,036	1,150	1,199	1,265	1,285	5.2
36	Petroleum and Coal Products	590	541	586	622	685	733	839	899	913	7.2
30	Metal Fabricating	490	571	643	641	702	709	776	803	844	6.3
18	Textile	396	442	535	565	627	526	652	678	765	7.3
33	Electrical Products	572	618	687	745	715	741	710	769	741	3.0
16	Rubber and Plastics Products	377	416	475	508	546	612	616	632	725	7.9
31	Machinery	288	787	326	357	365	407	412	441	492	1.7
28	Printing, Publishing and Allied	152	160	183	187	198	212	226	333	264	6.7
25	Wood	97	103	123	121	126	137	152	186	204	9.2
26	Furniture and Fixtures	53	60	73	81	94	96	102	106	117	10.0
17	Leather	46	47	51	55	60	64	61	61	61	4.1
15	Tobacco Products	27	34	36	41	44	51	57	62	58	10.5
23	Knitting	20	29	33	33	37	37	40	41	47	8.6
24	Clothing	28	30	34	36	39	38	36	38	39	3.7
	Total	16,307	17,777	19,541	19,941	21,353	21,671	23,084	23,638	24,513	5.0

[1]Industries are listed based on their 1972 purchases.

Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report No: PMA-75-5.

TABLE A-2b

PERCENTAGE DISTRIBUTION OF TOTAL KILOWATT-HOUR SALES
TO ONTARIO HYDRO'S INDUSTRIAL USERS BY TWO-DIGIT INDUSTRIES

1964 - 1972

SIC Code	Industry	1964	1965	1966	1967	1968	1969	1970	1971	1972
		(Percent)								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
29	Primary Metal	22.9%	24.0%	22.6%	23.1%	23.5%	20.9%	23.3%	23.1%	23.1%
27	Paper and Allied	22.4	21.1	20.8	19.7	19.0	19.8	18.3	18.0	18.7
37	Chemical and Chemical Products	15.9	15.6	17.0	17.3	17.8	18.0	17.9	16.9	14.8
35	Non-Metallic Mineral Products	8.5	8.7	8.7	7.8	7.5	7.7	7.5	7.2	7.8
32	Transportation	5.0	5.7	5.7	6.1	6.6	7.3	6.5	7.5	7.7
10	Food and Beverage	5.3	5.2	4.9	5.1	4.9	5.3	5.2	5.4	5.2
36	Petroleum and Coal Products	3.6	3.0	3.0	3.1	3.2	3.4	3.6	3.8	3.7
30	Metal Fabricating	3.0	3.2	3.3	3.2	3.3	3.3	3.4	3.4	3.4
18	Textile	2.4	2.5	2.7	2.8	2.9	2.4	2.8	2.9	3.1
33	Electrical Products	3.5	3.5	3.5	3.7	3.3	3.4	3.1	3.3	3.0
16	Rubber and Plastics Products	2.3	2.3	2.4	2.6	2.6	2.8	2.7	2.7	3.0
31	Machinery	1.8	1.6	1.7	1.8	1.7	1.9	1.8	1.9	2.0
28	Printing, Publishing and Allied	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1
25	Wood	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.8	0.8
26	Furniture and Fixtures	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5
17	Leather	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2
15	Tobacco Products	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2
23	Knitting	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
24	Clothing	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: Table II-2A.

TOTAL ENERGY AND KILOWATT-HOUR SALES
TO ONTARIO HYDRO'S USERS

1964 - 1972

	Total Energy Consumption (MMBtu)	Number of Establishments	Average Energy Consumption per Establishment (MMBtu)
	(1)	(2)	(3)
1964	342,766,825	11,585	29,587
1965	374,151,490	11,559	32,369
1966	395,700,942	11,763	33,639
1967	402,311,890	11,842	33,973
1968	410,391,264	11,718	35,022
1969	405,962,726	11,909	34,089
1970	429,052,239	11,707	36,649
1971	439,004,413	11,661	37,647
1972	464,828,405	11,508	40,392
Annual Rate of Growth	3.2%		3.2%

TOTAL ENERGY AND K .TT-HOUR SALES
TO ONTARIO HYDRO'S USERS

1964 - 1972

	Total Kilowatt-hour Consumption (MMBtu)	Number of Establishments	Average Kilowatt-hour Consumption per Establishments (MMBtu)	Electrical Energy as Percent of Total Energy
	(4)	(5)	(6)	(7)
1964	55,639,764	11,585	4,803	16.2
1965	60,655,049	11,559	5,247	16.2
1966	66,673,909	11,763	5,668	16.8
1967	68,038,975	11,842	5,246	16.9
1968	72,857,251	11,718	6,218	17.8
1969	73,943,114	11,909	6,209	18.2
1970	78,762,509	11,707	6,728	18.4
1971	80,654,398	11,661	6,917	18.4
1972	83,636,817	11,508	7,268	18.0
Annual Rate of Growth	5.0%		5.0%	

Conversion factors used were:

Coal: 25.2 MMBtu/short ton
Gasln: 5.245 MMBtu/Bbl
F Oil: 5.8275 MMBtu/Bbl
N Gas: (a)
LPG: 4.095 MMBtu/Bbl
Elec.: 3.412 MMBtu/thousand Kwh

(a) 1.035 MMBtu/Mcf in 1964
1.02 MMBtu/Mcf in 1965
1.01 MMBtu/Mcf in 1966
1.00 MMBtu/Mcf between 1967 and 1972.

Source: Ontario Hydro, Trends in Energy Use Within Ontario Industries, 1964-1972, Report NO: PMA0-75-5.

TABLE A-4a

TOTAL ENERGY SALES TO ONTARIO HYDRO'S INDUSTRIAL USERS
BY TWO-DIGIT INDUSTRIES[1]

1964 - 1972

SIC Code	Industry	1964	1965	1966	1967	1968	1969	1970	1971	1972	Annual Rate of Growth (Percent)
		(Billions of Btu)									
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
29	Primary Metal	80,397	92,666	92,875	93,720	97,360	84,600	100,624	87,759	104,136	1.6%
27	Paper and Allied	66,893	68,773	71,054	74,338	72,894	75,874	77,429	75,484	78,940	1.9
37	Chemical and Chemical Products	51,715	54,275	63,398	63,935	62,572	64,254	65,744	66,959	75,303	3.8
35	Non-Metallic Mineral Products	38,634	42,567	43,491	42,342	44,169	46,869	48,449	51,778	57,138	4.2
10	Food and Beverage	32,959	34,997	36,366	36,994	36,987	36,454	36,816	37,417	37,759	1.3
32	Transportation	19,077	21,655	25,190	25,780	27,998	26,050	25,327	27,377	29,504	4.2
30	Metal Fabricating	11,370	12,713	13,758	13,478	13,804	15,854	16,369	15,799	17,076	4.8
18	Textile	8,080	8,503	9,355	9,310	10,459	10,346	10,512	10,294	12,338	4.4
16	Rubber and Plastic Products	6,437	7,011	7,727	8,386	8,531	9,264	9,237	9,133	10,400	5.4
33	Electrical Products	8,558	9,186	9,338	10,083	10,245	10,110	9,663	9,670	9,794	1.3
31	Machinery	5,429	5,969	6,672	7,005	6,899	7,091	7,106	7,242	7,969	3.8
36	Petroleum and Coal Products	2,354	2,065	3,472	3,769	4,613	4,777	5,766	6,264	6,324	15.3
25	Wood	1,773	1,873	2,233	2,173	2,240	2,532	2,854	3,737	4,262	10.9
28	Printing, Publishing and Allied	1,970	2,128	2,313	2,282	2,254	2,337	2,426	2,535	2,756	3.4
26	Furniture and Fixture	1,274	1,382	1,626	1,626	1,798	1,970	2,034	2,136	2,237	7.2
17	Leather	1,606	1,607	1,525	1,531	1,658	1,645	1,569	1,799	1,583	0.7
23	Knitting	867	956	981	1,111	988	991	1,210	1,168	1,256	4.0
15	Tobacco Products	545	542	603	687	677	733	793	833	730	5.3
24	Clothing	482	523	560	575	581	581	544	508	564	0.8

[1]Industries are listed based on their 1972 purchases.

Source: Ontario Hydro, Trends in Energy Use Within Ontario Hydro Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

TOTAL ENERGY AND K[illegible]TT-HOUR SALES

PERCENTAGE DISTRIBUTION OF TOTAL ENERGY SALES
TO ONTARIO HYDRO'S INDUSTRIAL USERS BY TWO-DIGIT INDUSTRIES

1964 - 1972

SIC Code	Industry	1964	1965	1966	1967	1968	1969	1970	1971	1972
		(Percent)								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
29	Primary Metal	23.5%	24.8%	23.5%	23.3%	23.7%	20.8%	23.5%	20.0%	22.4%
27	Paper and Allied	19.5	18.4	18.0	18.5	17.8	18.7	18.1	17.2	17.0
37	Chemical and Chemical Products	15.1	14.5	16.0	15.9	15.2	15.8	15.3	15.3	16.2
35	Non-Metallic Mineral Products	11.3	11.4	11.0	10.5	10.8	11.5	11.3	11.8	12.3
10	Food and Beverage	9.6	9.4	9.2	9.2	9.0	9.0	8.6	8.5	8.1
32	Transportation	5.6	5.8	6.4	6.4	6.8	6.4	5.9	6.2	6.3
30	Metal Fabricating	3.3	3.4	3.5	3.4	3.4	3.9	3.8	3.6	3.7
18	Textile	2.4	2.3	2.4	2.3	2.5	2.5	2.5	2.3	2.7
16	Rubber and Plastic Products	1.9	1.9	2.0	2.1	2.1	2.3	2.2	2.1	2.2
33	Electrical Products	2.5	2.5	2.4	2.5	2.5	2.5	2.3	2.2	2.1
31	Machinery	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.6	1.7
36	Petroleum and Coal Products	0.7	0.6	0.9	0.9	1.1	1.2	1.3	1.4	1.4
25	Wood	0.5	0.5	0.6	0.5	0.5	0.6	0.7	0.9	0.9
28	Printing, Publishing and Allied	0.6	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.6
26	Furniture and Fixture	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5
17	Leather	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3
23	Knitting	0.3	0.3	0.2	0.3	0.2	0.2	0.3	0.3	0.3
15	Tobacco Products	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
24	Clothing	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Table II-4A.

TABLE A-5

AVERAGE ENERGY SALES PER ESTABLISHMENT
TO ONTARIO HYDRO'S INDUSTRIAL USERS BY TWO-DIGIT INDUSTRIES

1964 - 1972

SIC Code	Industry	1964	1965	1966	1967	1968	1969	1970	1971	1972	Annual Rate of Growth
		(Millions of Btu)									(Percent)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
29	Primary Metal	394,101	454,245	442,260	437,943	470,338	391,667	474,641	430,191	493,534	1.3%
27	Paper and Allied	250,534	259,520	257,444	266,444	253,985	260,734	273,599	261,190	263,133	0.5
36	Petroleum and Coal Products	94,163	82,587	138,879	139,580	177,438	164,735	205,927	195,760	191,638	11.2
37	Chemical and Chemical Products	91,693	95,723	108,188	110,807	105,518	111,167	114,337	116,451	131,190	3.6
35	Non-Metallic Mineral Products	72,757	80,773	80,990	83,351	85,764	90,306	91,586	96,421	109,881	4.3
32	Transportation	59,804	66,632	74,526	73,239	77,989	72,968	69,770	70,378	75,459	1.6
15	Tobacco Products	30,289	30,129	37,662	45,772	52,060	56,353	60,992	64,103	56,116	10.3
18	Textile	21,898	22,674	24,489	24,056	26,817	27,012	27,375	26,947	32,727	4.2
16	Rubber and Plastics Products	26,168	27,279	27,209	27,861	27,168	28,769	28,777	27,262	29,886	1.1
10	Food and Beverage	12,760	14,226	15,241	16,001	17,292	17,791	19,215	20,458	21,813	6.5
33	Electrical Products	22,641	24,237	22,775	23,558	23,283	22,466	21,284	20,530	21,432	-1.5
31	Machinery	13,850	14,383	15,232	15,296	14,314	14,238	14,015	13,561	14,594	-0.4
23	Knitting	7,045	7,646	8,317	9,661	8,818	9,176	11,521	12,117	13,360	7.9
17	Leather	7,649	7,839	7,475	7,851	8,501	8,186	8,345	9,996	9,479	3.1
30	Metal Fabricating	6,542	6,962	7,117	6,672	6,750	7,674	7,725	7,326	8,135	2.2
25	Wood	2,054	2,292	2,270	2,660	2,883	3,266	3,780	5,098	5,814	13.9
26	Furniture and Fixture	1,382	1,499	1,737	1,733	1,939	2,087	2,262	2,446	2,601	8.2
28	Printing, Publishing and Allied	1,533	1,626	1,739	1,676	1,646	1,475	1,551	1,610	1,716	0.1
24	Clothing	879	972	1,022	1,066	1,101	1,105	1,106	1,109	1,259	3.4

Source: Ontario Hydro, Trends in Energy Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

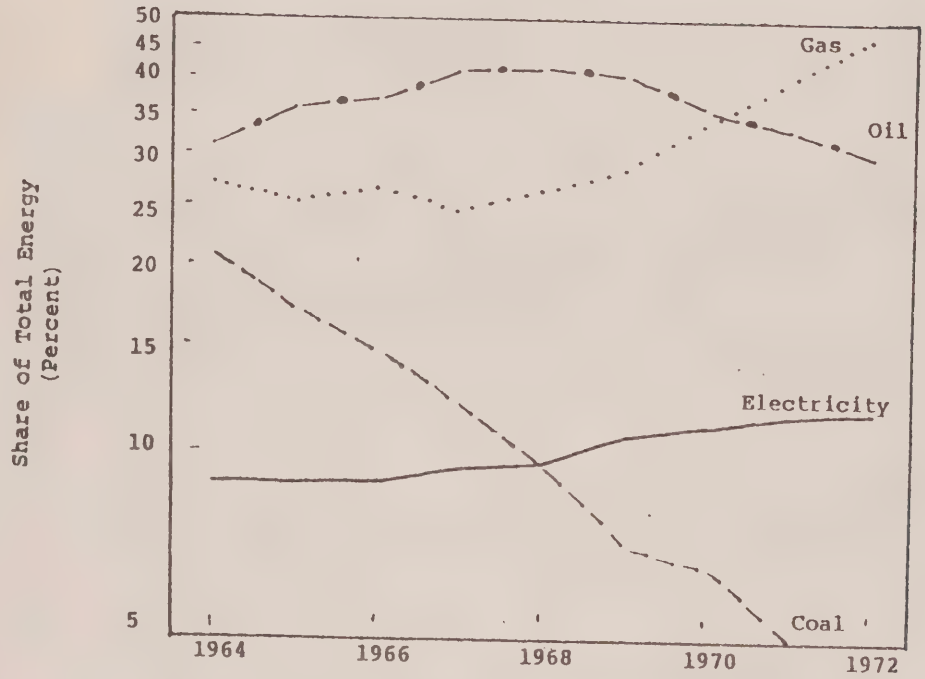
FIGURE A

PERCENTAGE BREAKDOWN OF TOTAL INDUSTRIAL ENERGY CONSUMED BY TWO-DIGIT INDUSTRY BY MAJOR FUEL

1964 - 1972

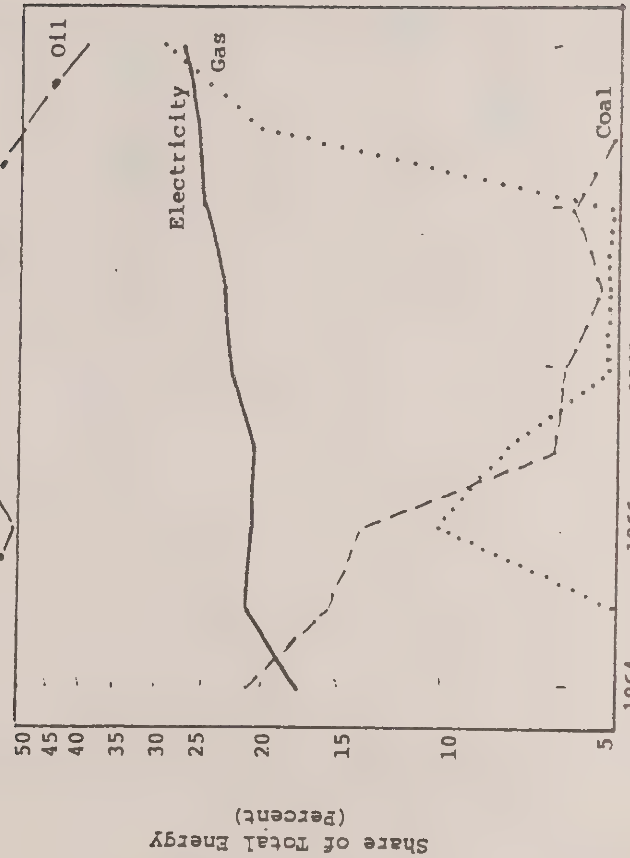
FIGURE A-1

FOOD AND BEVERAGE PRODUCTS, SIC 10



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

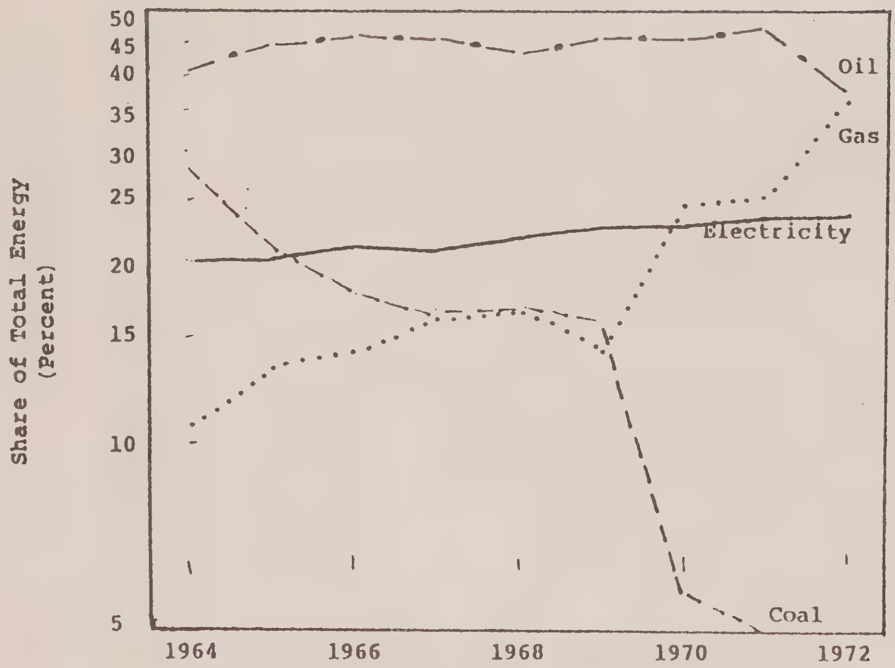
TOBACCO PRODUCTS, SIC 15



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE A-

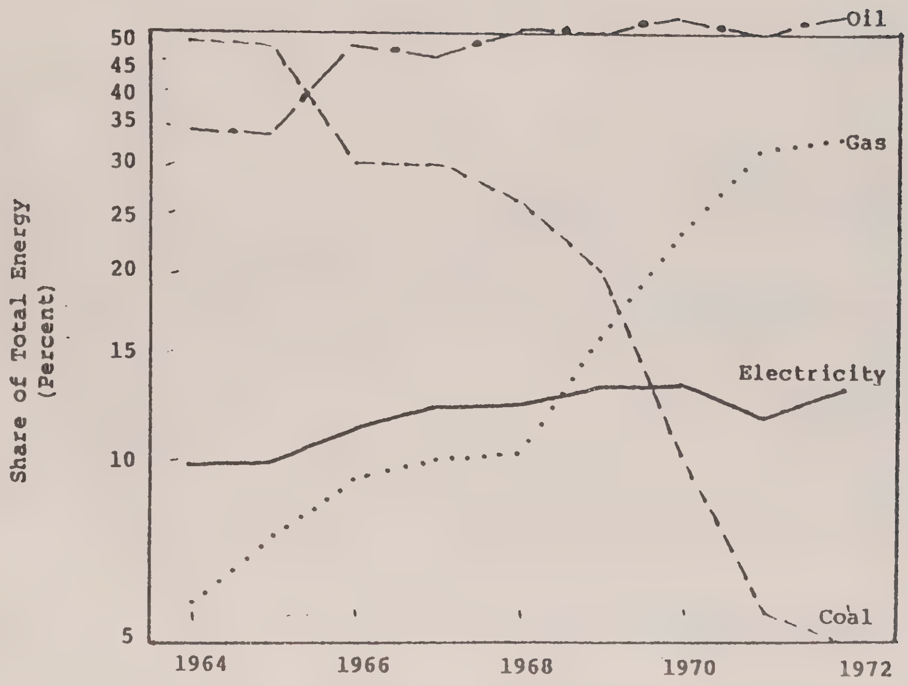
RUBBER AND PLASTICS PRODUCTS, SIC 16



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE A-4

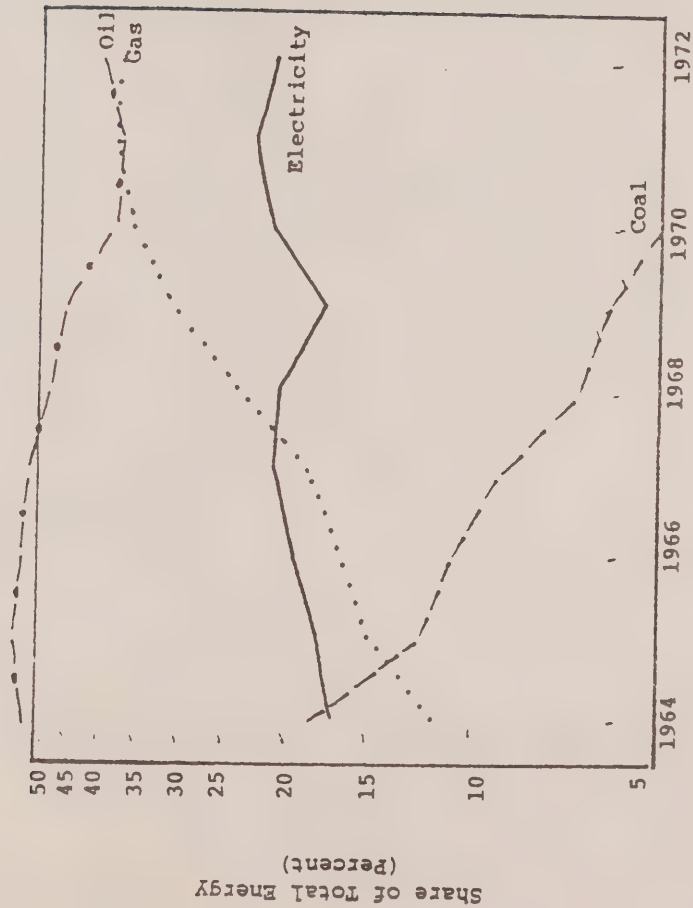
LEATHER PRODUCTS, SIC 17



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE A-5

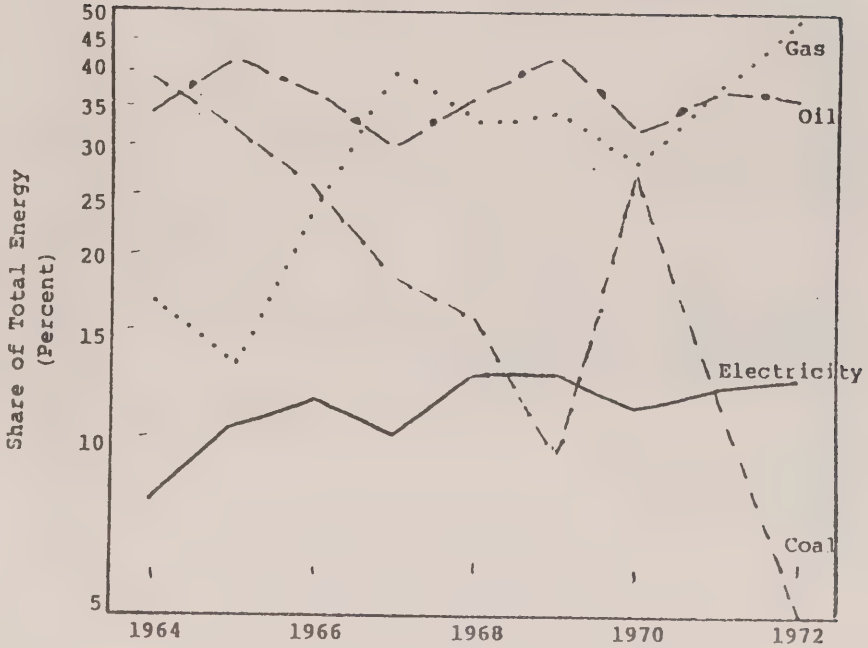
TEXTILE PRODUCTS, SIC 18



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE A-6

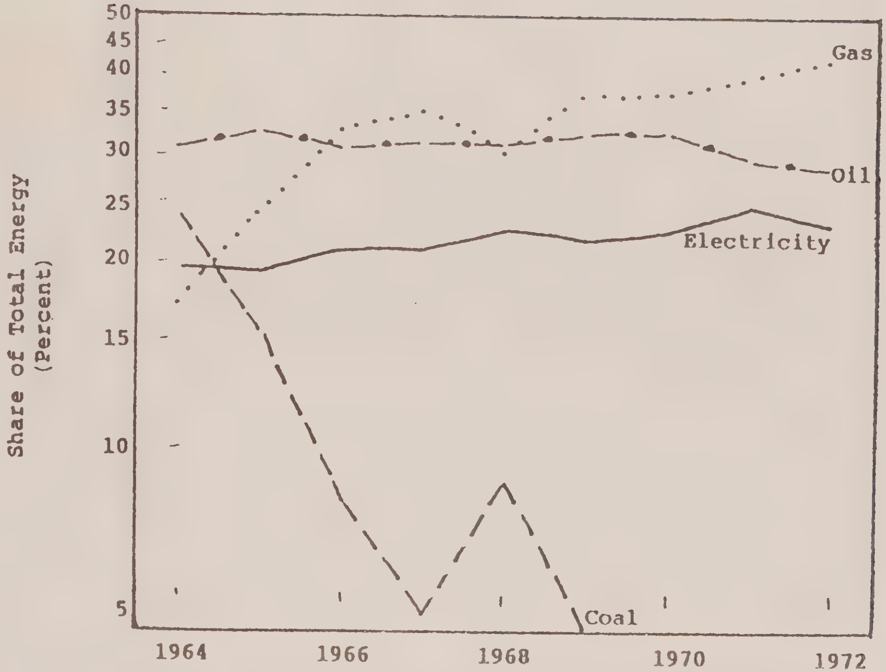
KNITTING PRODUCTS, SIC 23



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE A-7

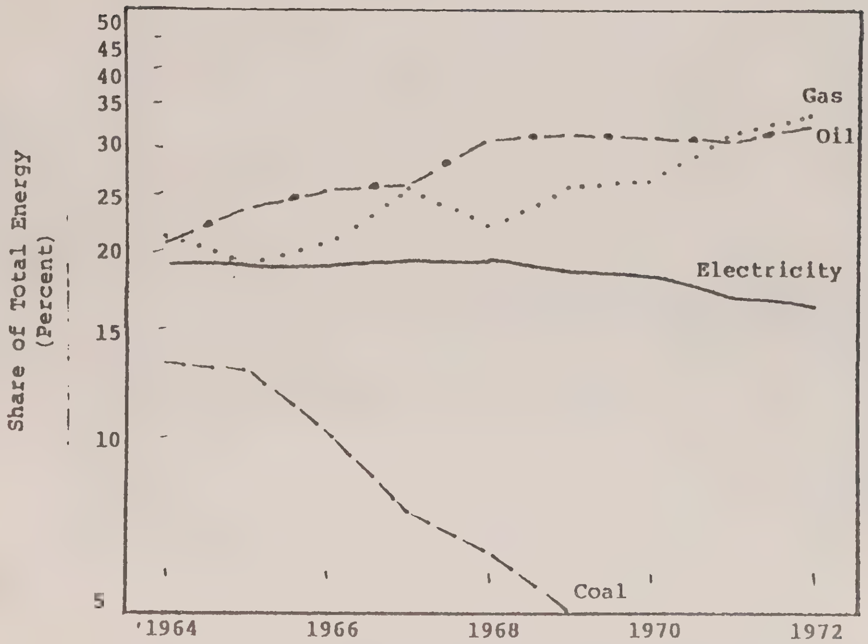
CLOTHING PRODUCTS, SIC 24



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE A-8

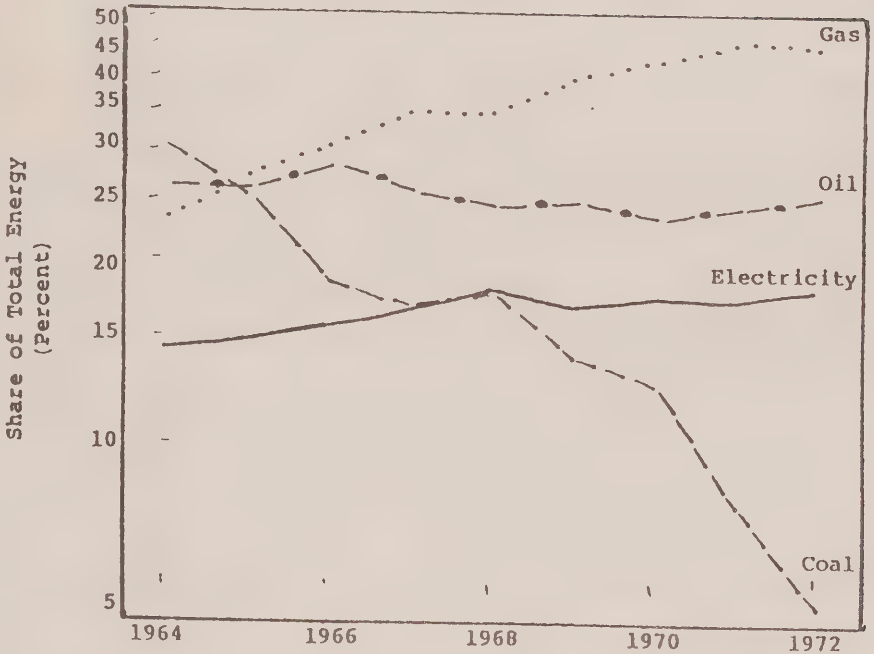
WOOD PRODUCTS, SIC 25



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

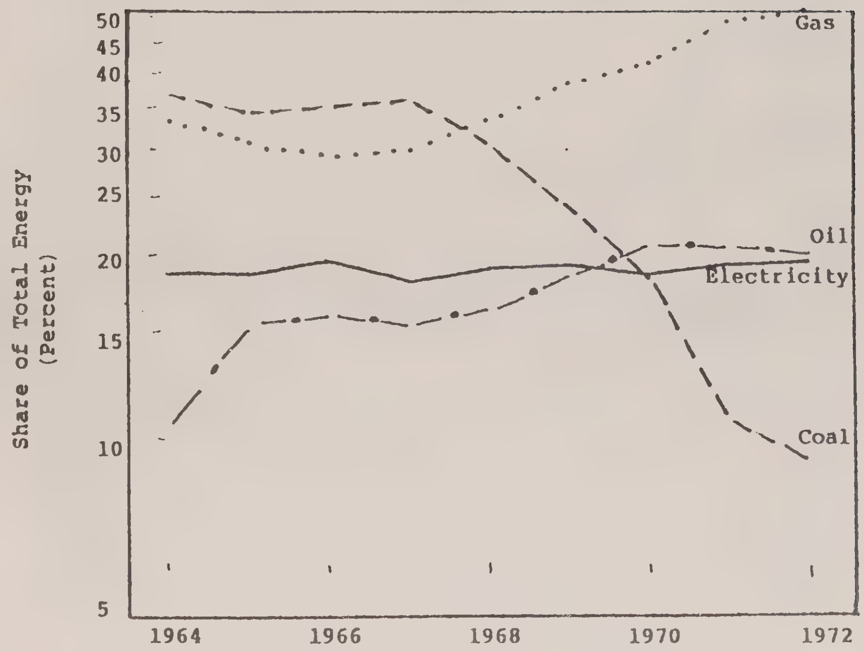
FIGURE A-9

FURNITURE AND FIXTURE PRODUCTS, SIC 26



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

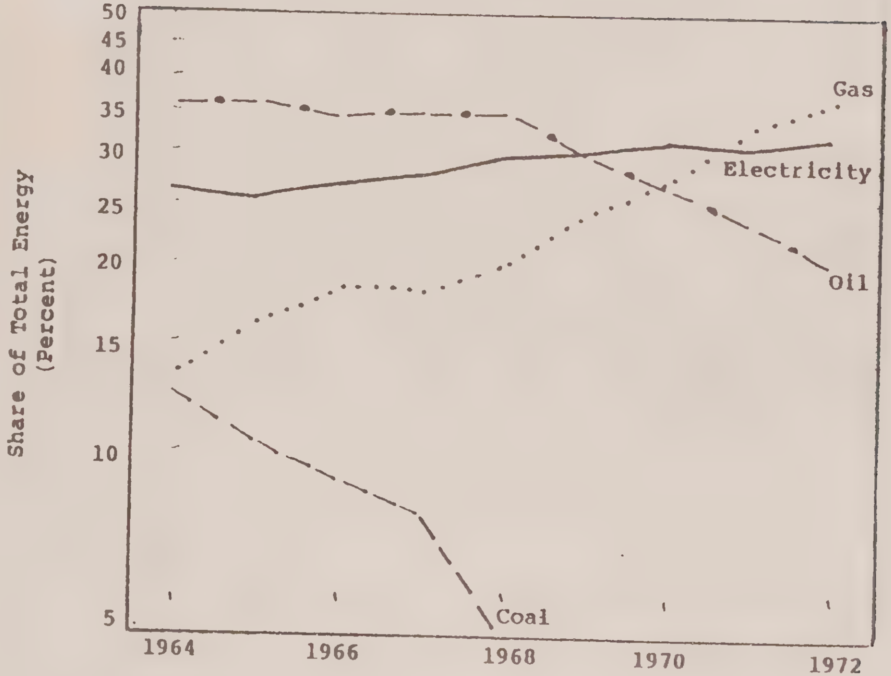
PAPER AND ALLIED PRODUCTS, SIC 27



Source: <u>Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972</u>, Report NO: PMA-75-5.

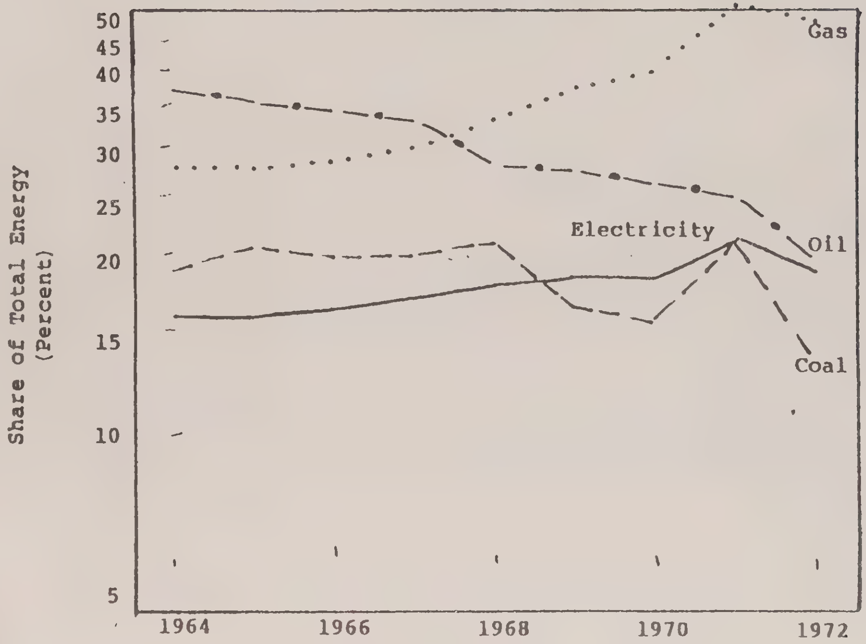
FIGURE A-11

PRINTING AND PUBLISHING PRODUCTS, SIC 28



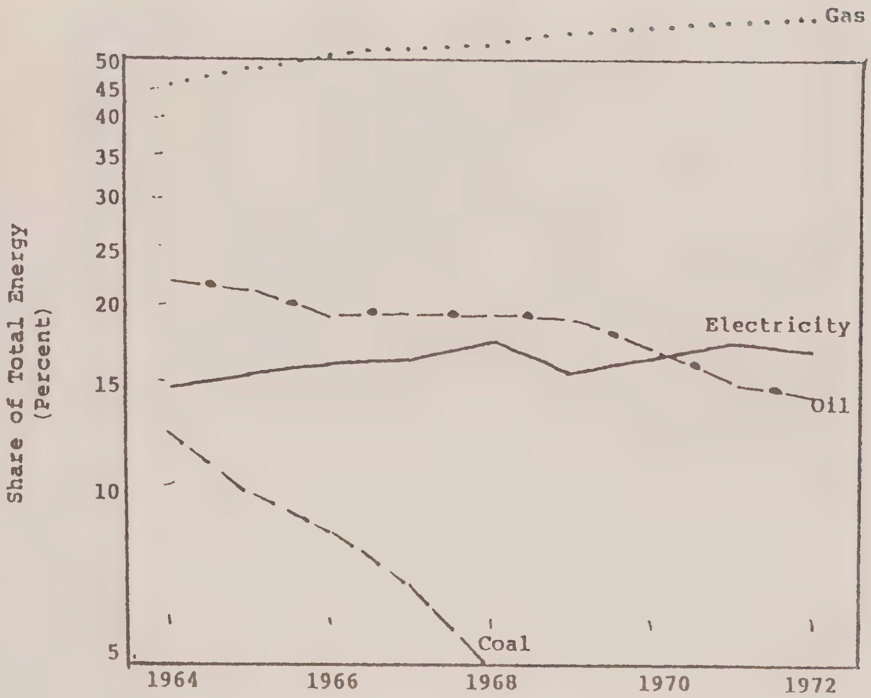
Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

PRIMARY METAL PRODUCTS, SIC 29



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

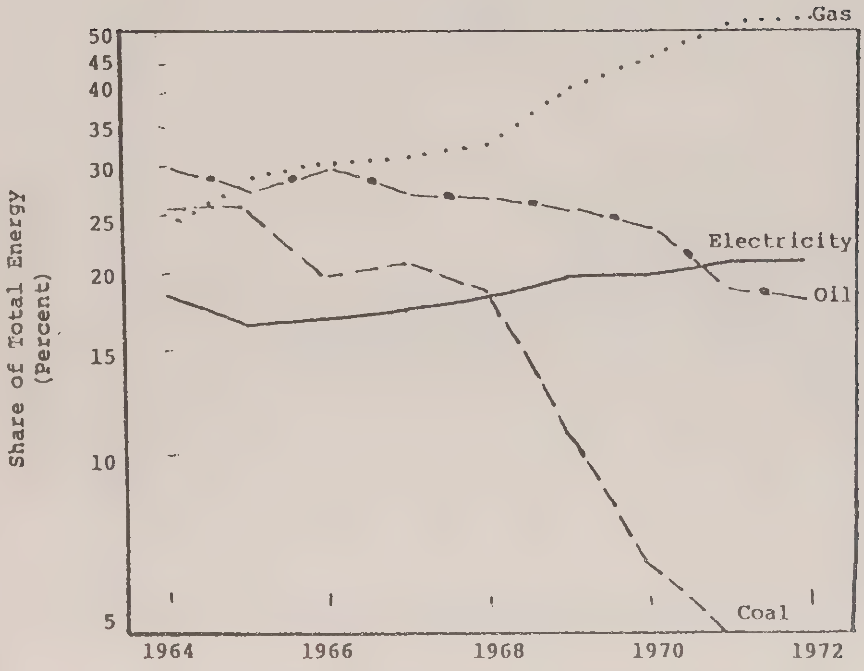
METAL FABRICATING PRODUCTS, SIC 30



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

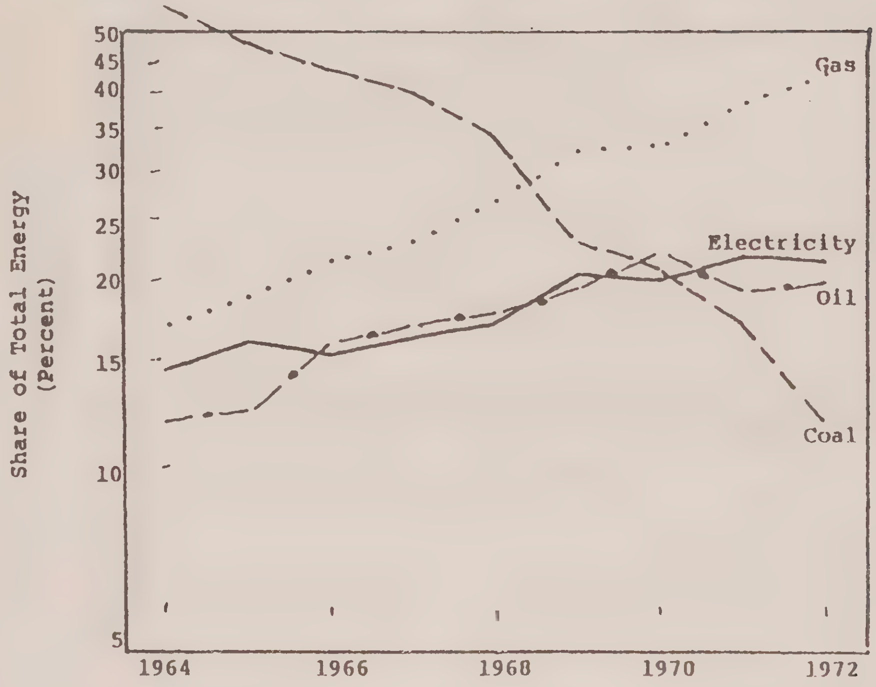
FIGURE A-14

MACHINERY PRODUCTS, SIC 31



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

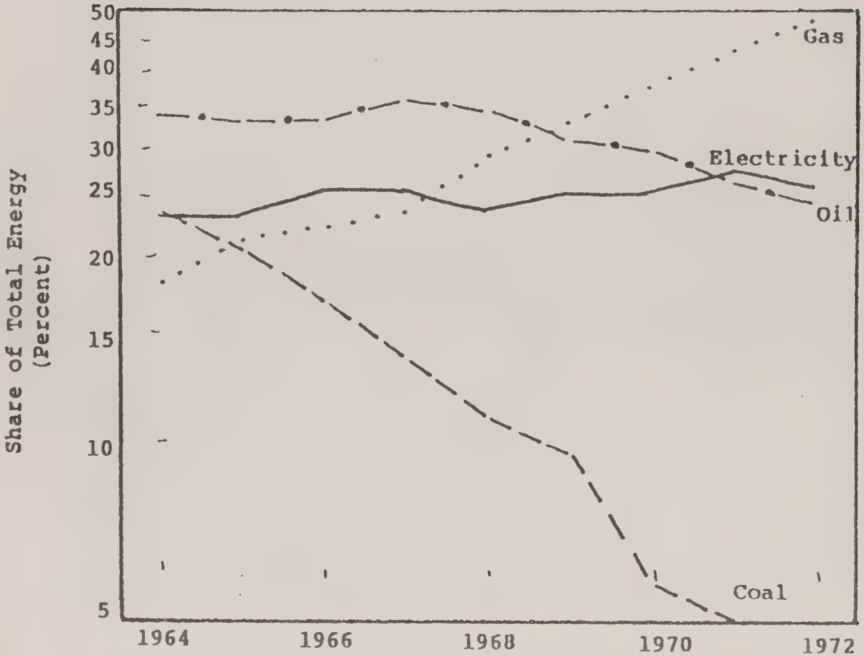
TRANSPORTATION EQUIPMENT PRODUCTS, SIC 32



Source: <u>Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972,</u> Report NO: PMA-75-5.

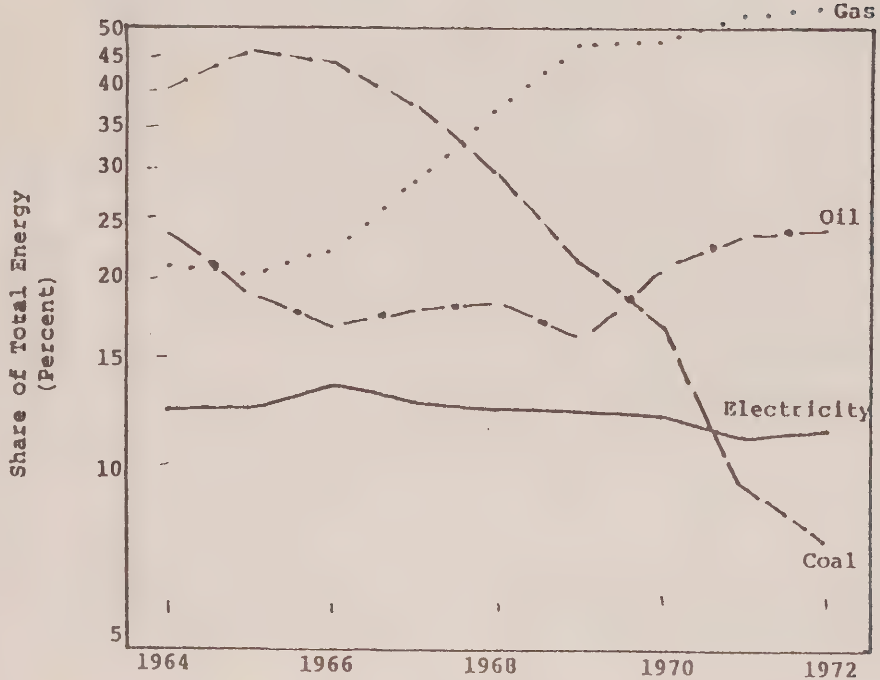
FIGURE A-16

ELECTRICAL PRODUCTS, SIC 33



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

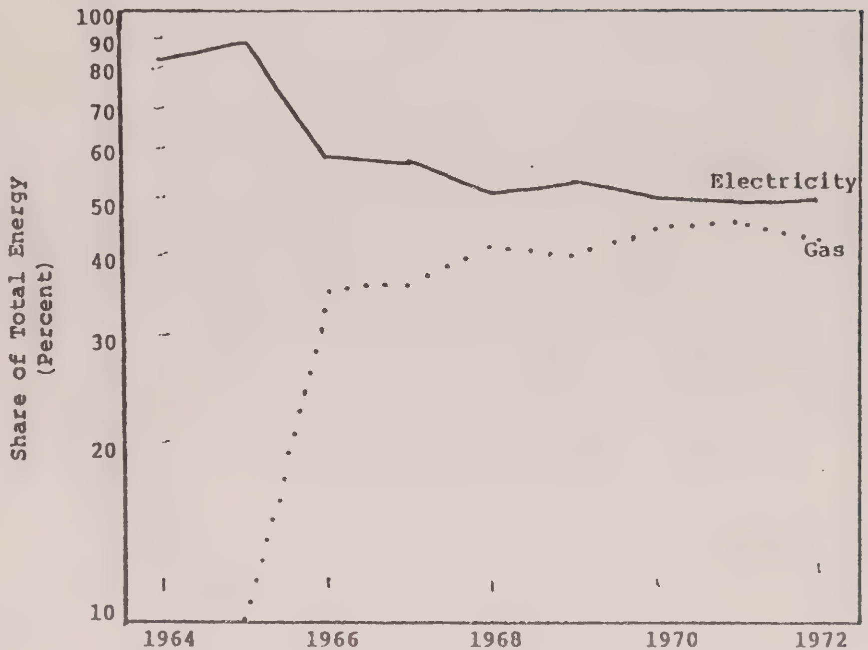
NON-METALLIC MINERAL PRODUCTS, SIC 35



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE A-18

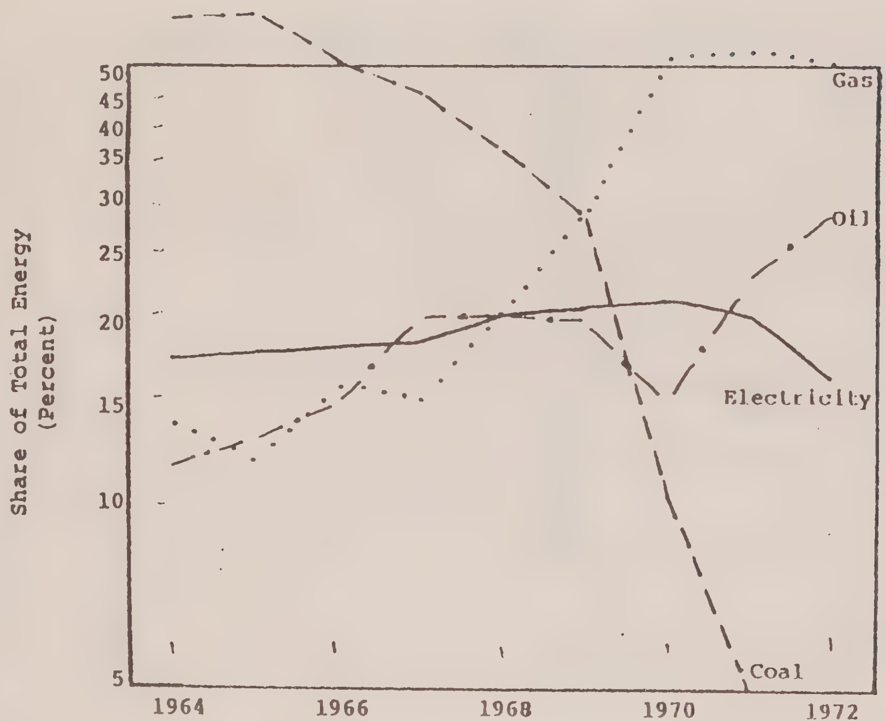
PETROLEUM AND COAL PRODUCTS, SIC 36



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE A-19

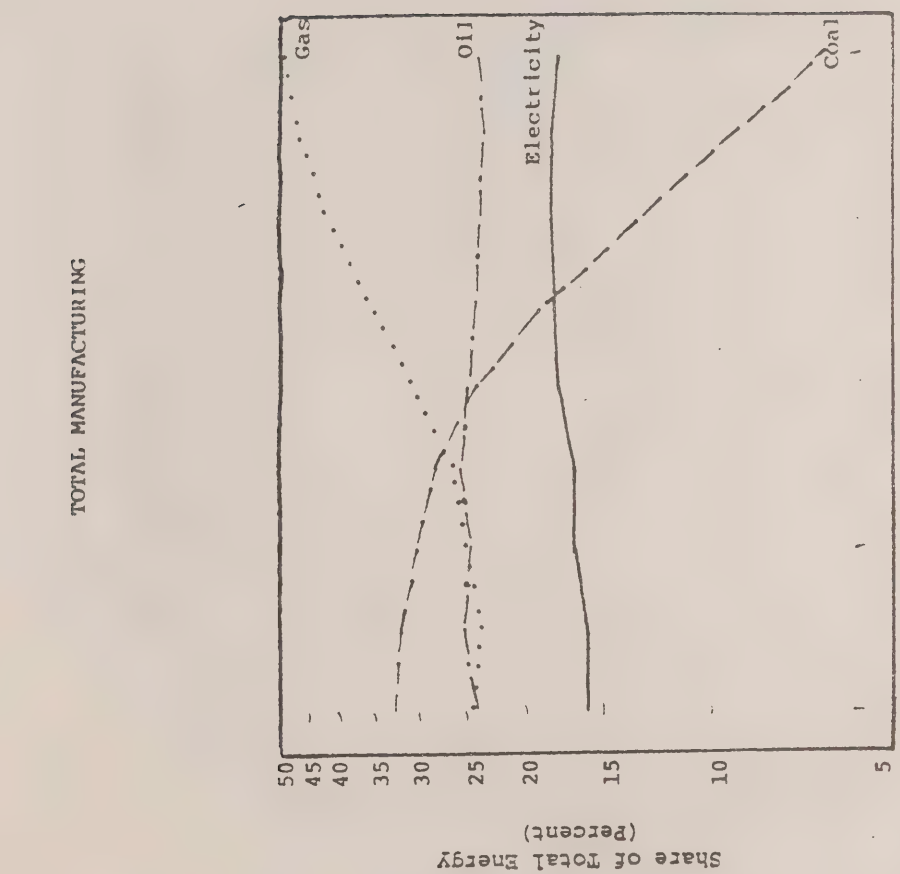
CHEMICAL AND CHEMICAL PRODUCTS, SIC 37



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE A-20

TOTAL MANUFACTURING



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

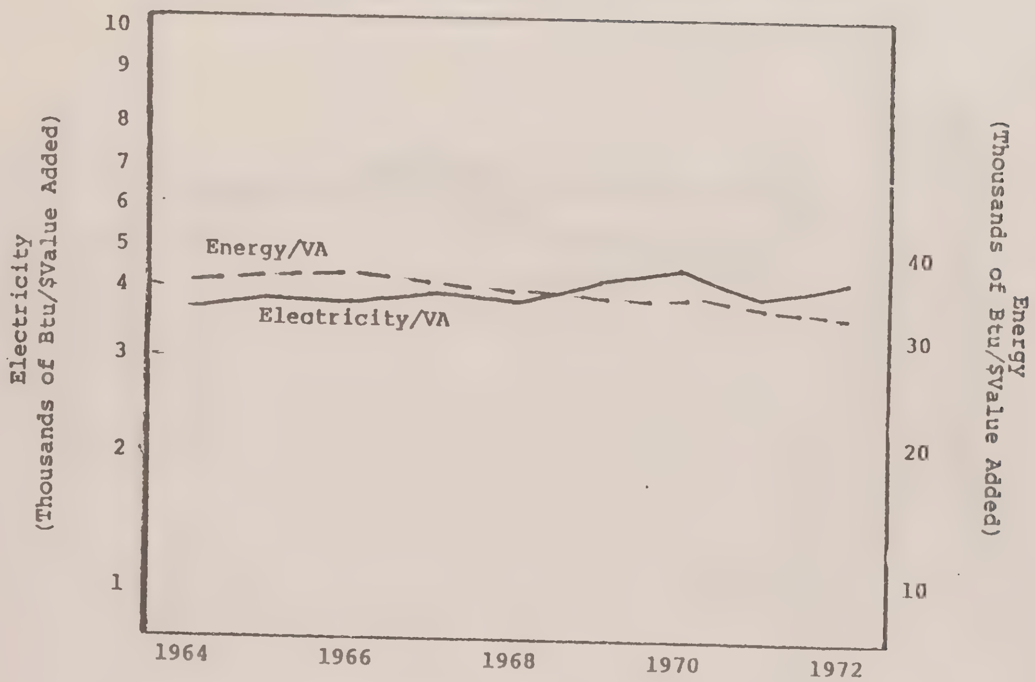
FIGURE B

TRENDS IN ELECTRICITY AND ENERGY INTENSIVENESS BY TWO-DIGIT INDUSTRY

1964 - 1972

FIGURE B-1

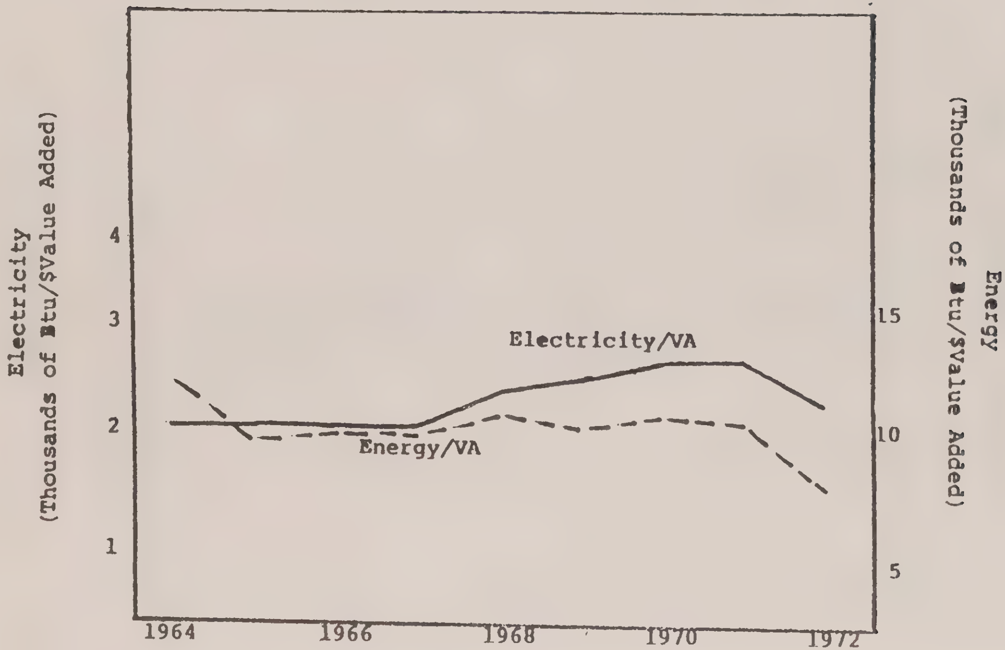
FOOD AND BEVERAGE PRODUCTS, SIC 10



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE B-2

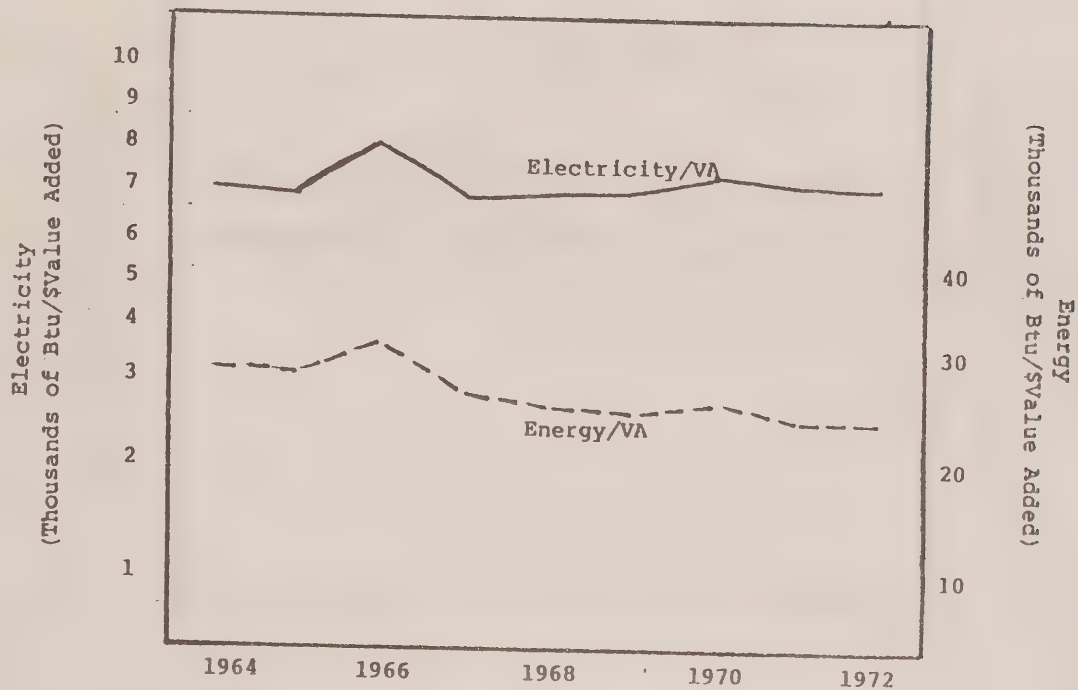
TOBACCO PRODUCTS, SIC 15



Source: <u>Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972</u>, Report NO: PMA-75-5.

FIGURE B-3

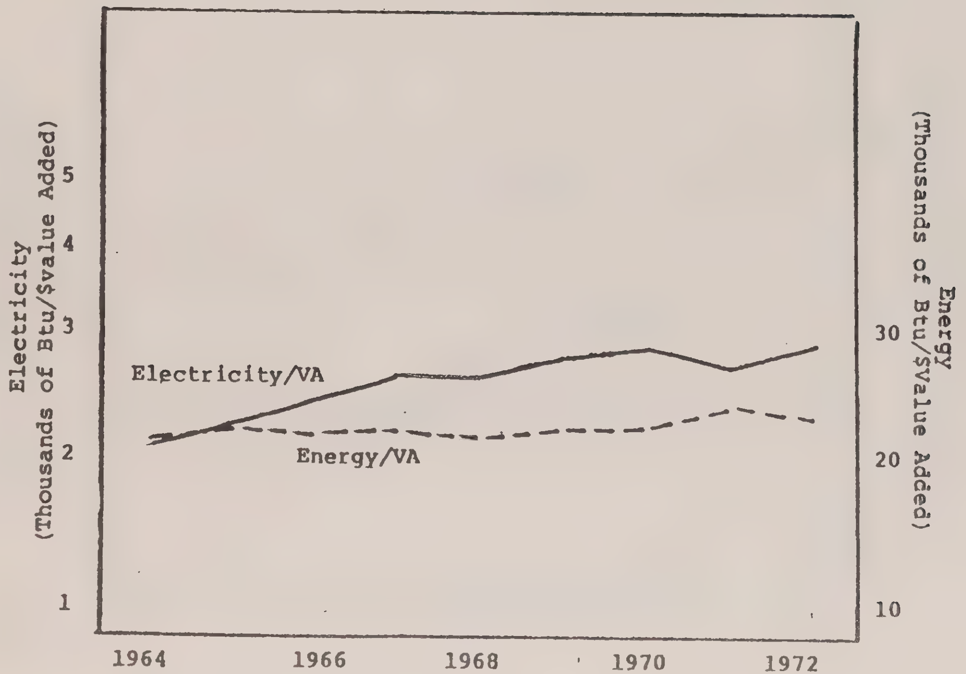
RUBBER AND PLASTICS PRODUCTS, SIC 16



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE B-4

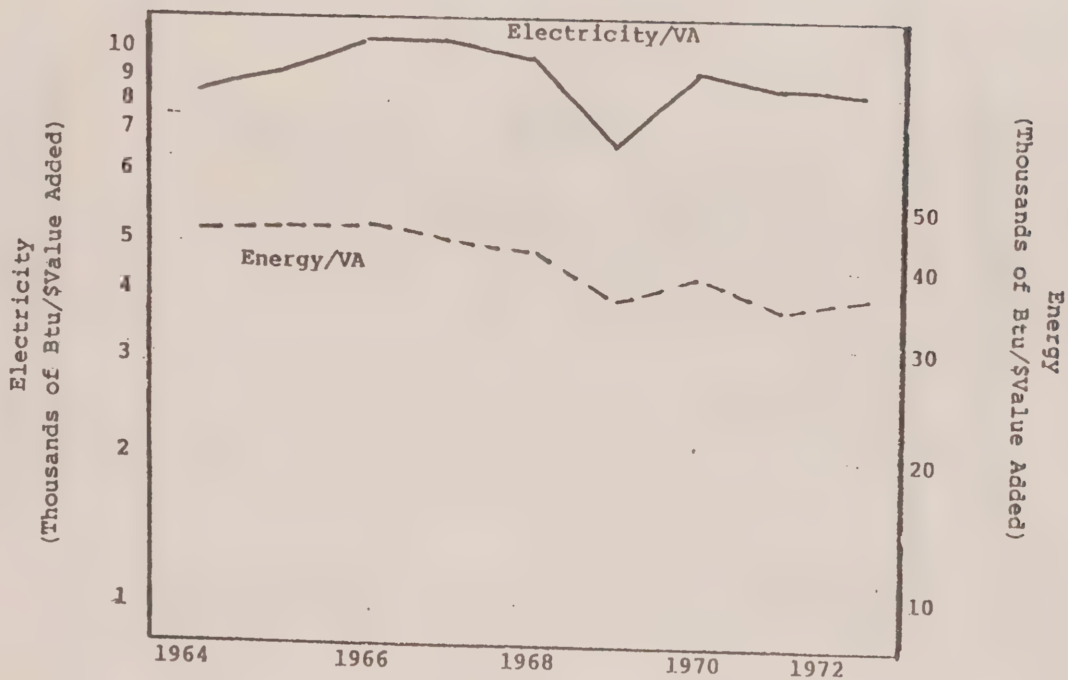
LEATHER PRODUCTS, SIC 17



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE B-5

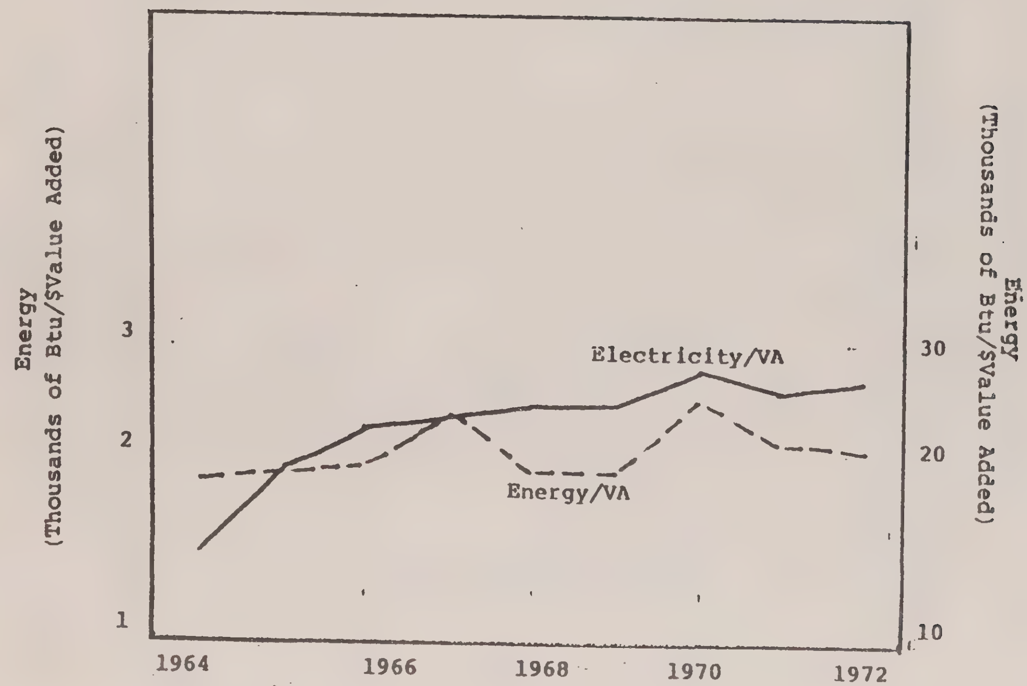
TEXTILE PRODUCTS, SIC 18



Source: <u>Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972</u>, Report NO: PMA-75-5.

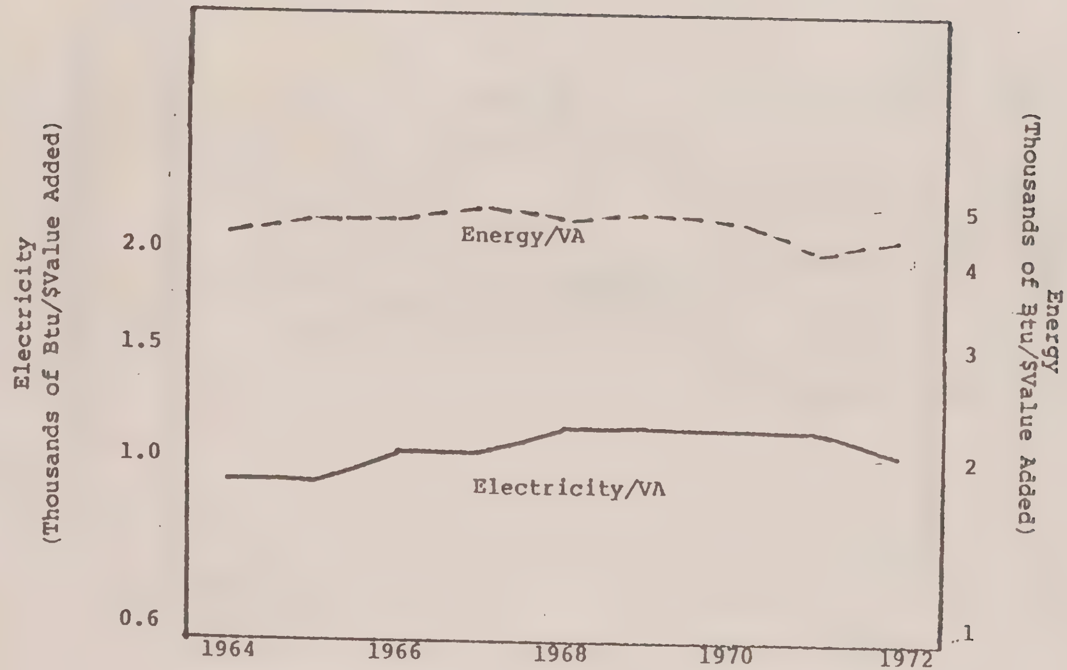
FIGURE B-6

KNITTING PRODUCTS, SIC 23



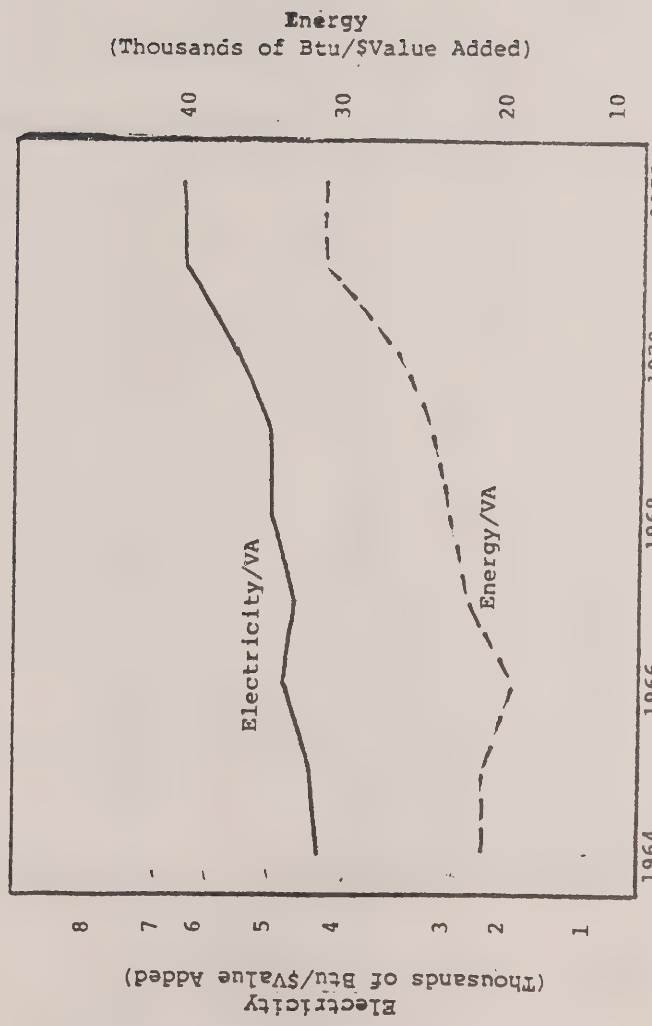
Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

CLOTHING PRODUCTS, SIC 24



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

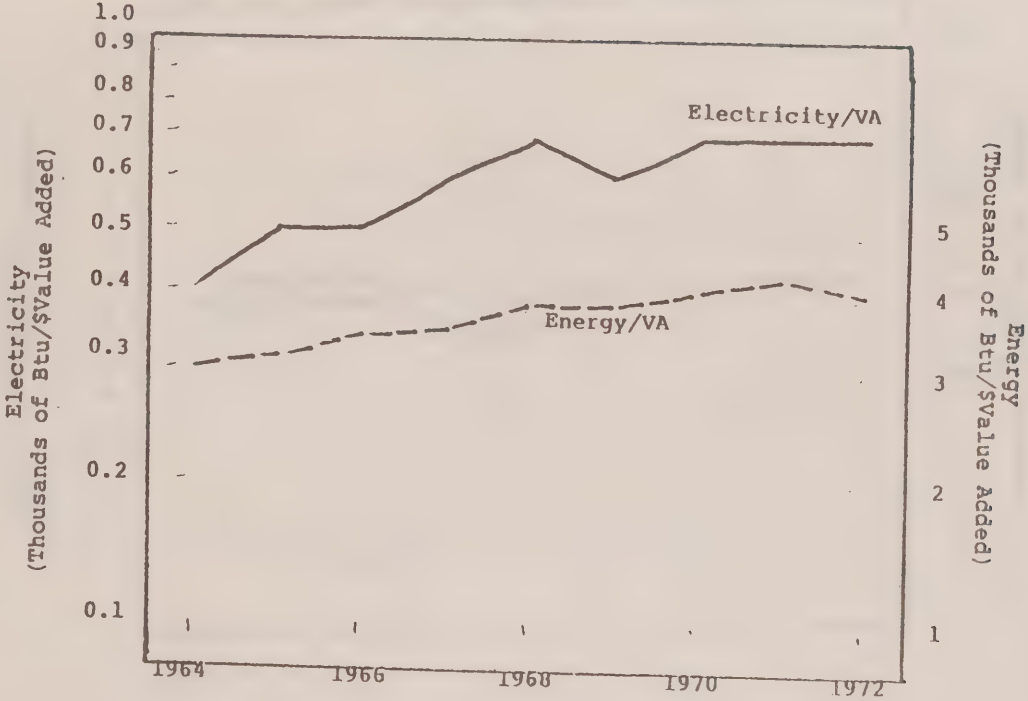
WOOD PRODUCTS, SIC 25



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

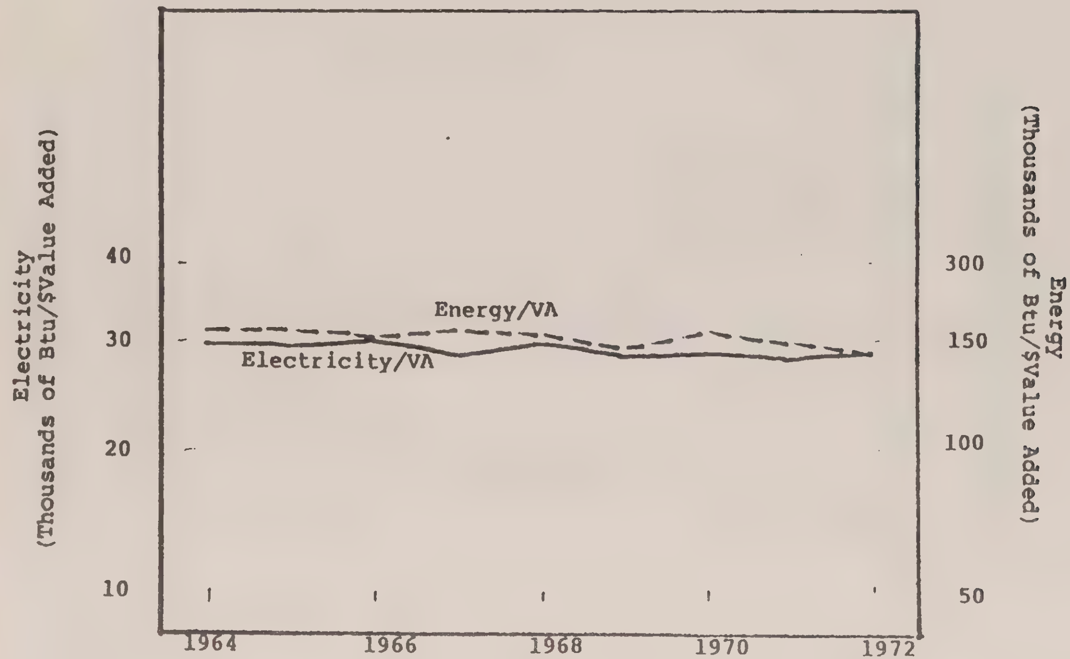
FIGURE B-9

FURNITURE AND FIXTURE PRODUCTS, SIC 26



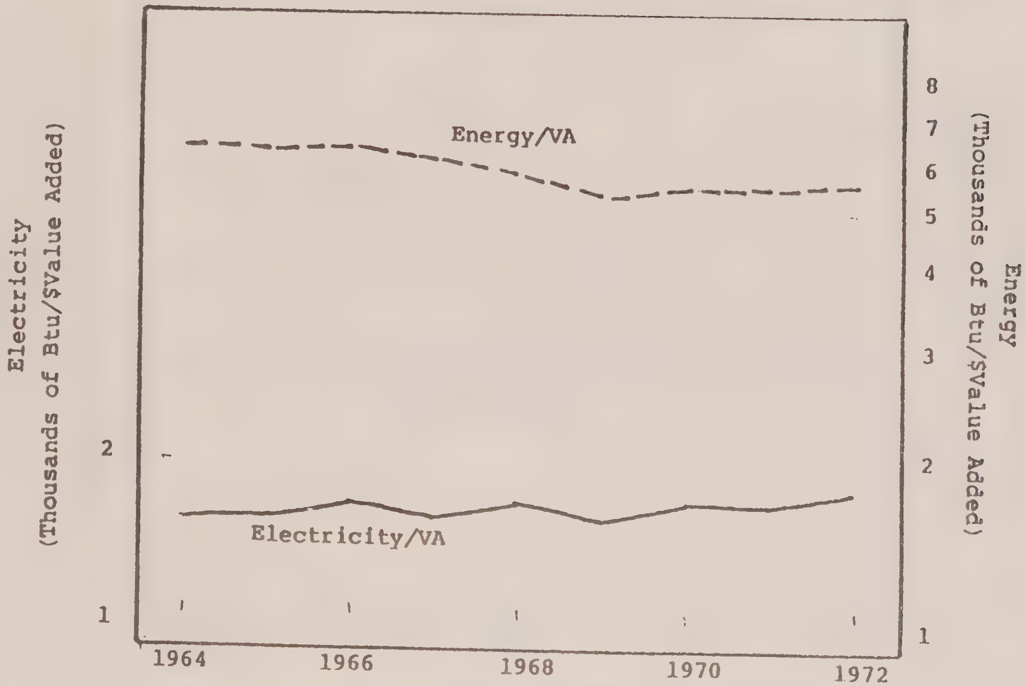
Source: <u>Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972</u>, Report NO: PMA-75-5.

PAPER AND ALLIED PRODUCTS, SIC 27



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

PRINTING AND PUBLISHING PRODUCTS, SIC 28

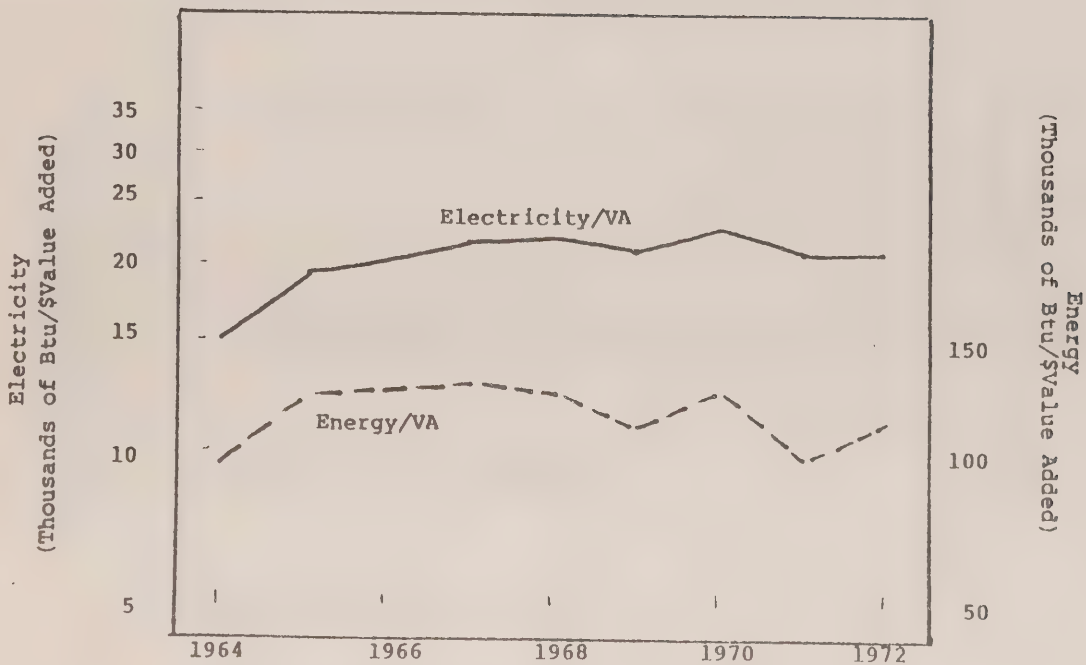


Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE B-11

FIGURE B-12

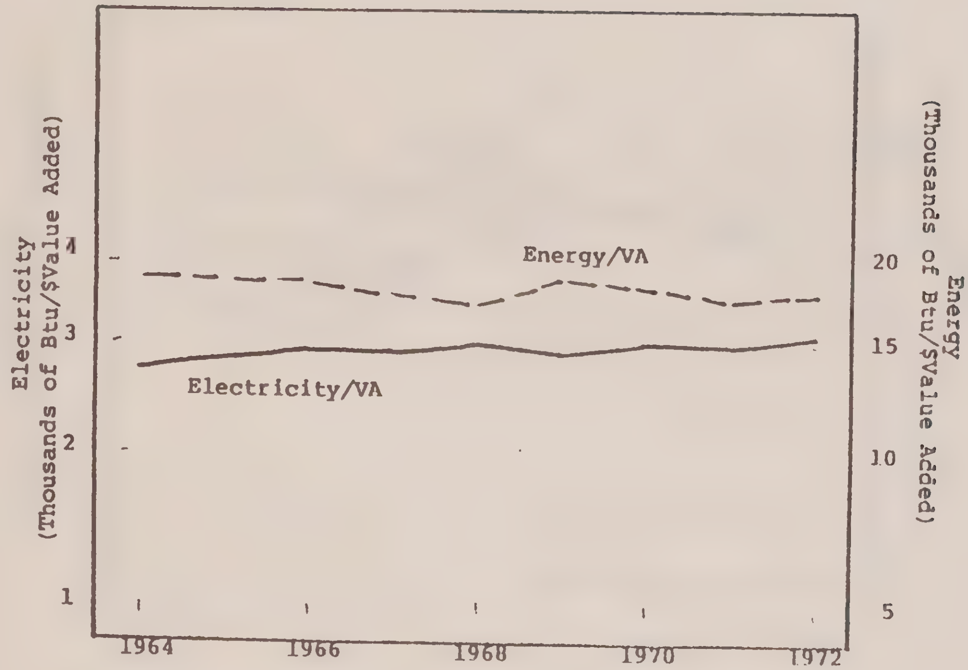
PRIMARY METAL PRODUCTS, SIC 29



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE B-13

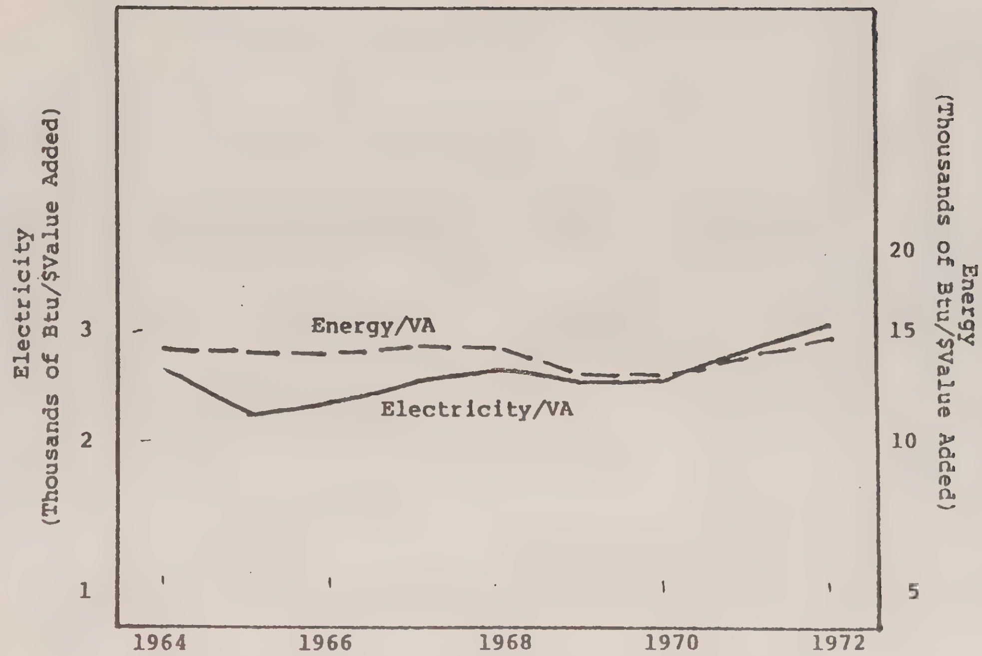
METAL FABRICATING PRODUCTS, SIC 30



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE B-14

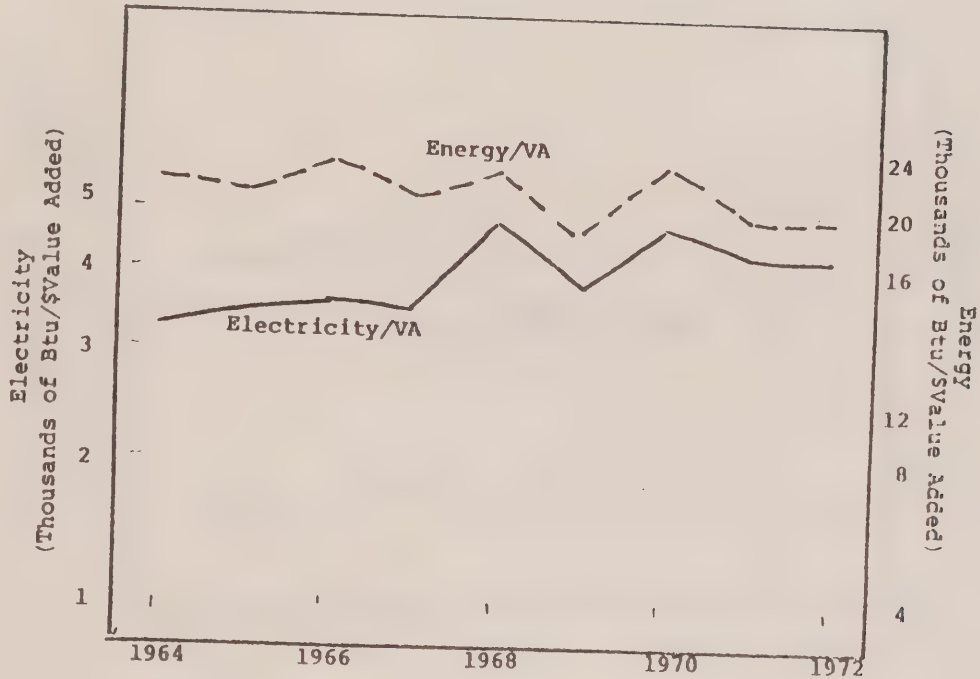
MACHINERY PRODUCTS, SIC 31



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

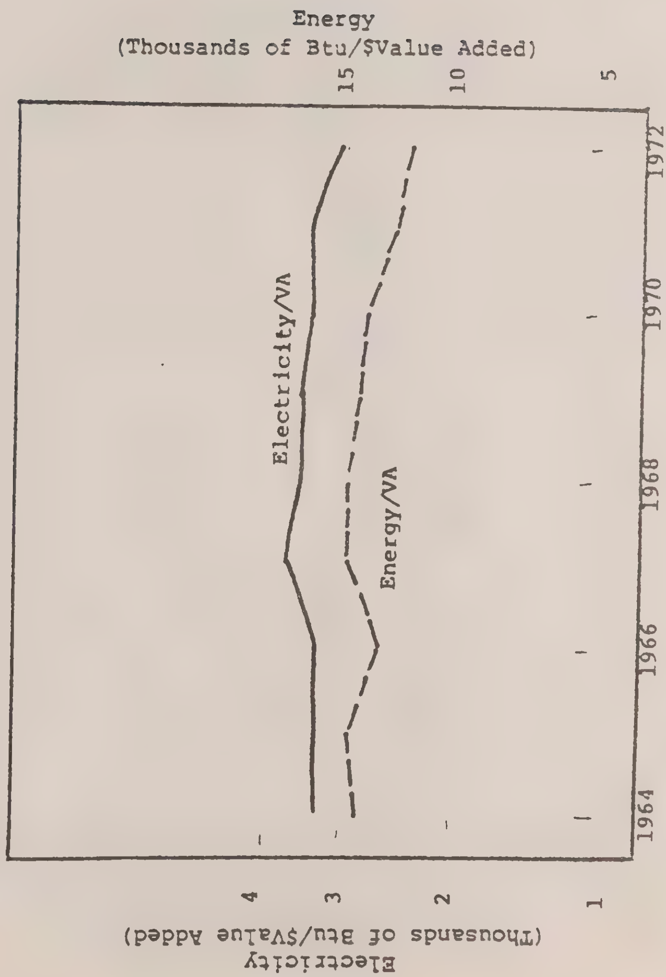
FIGURE B-15

TRANSPORTATION EQUIPMENT PRODUCTS, SIC 32



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

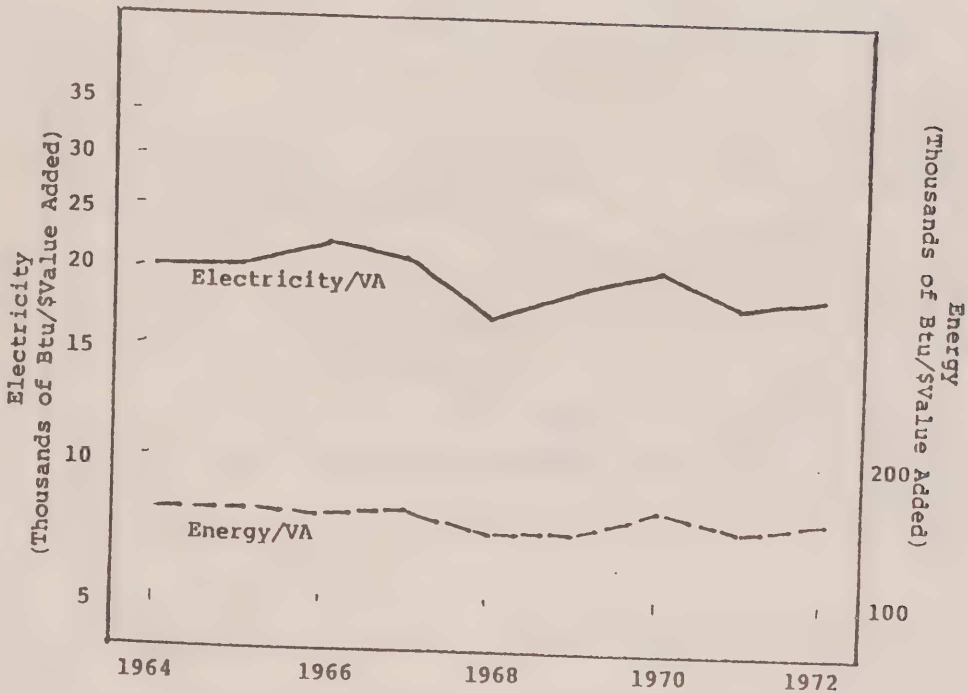
ELECTRICAL PRODUCTS, SIC 33



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE B-17

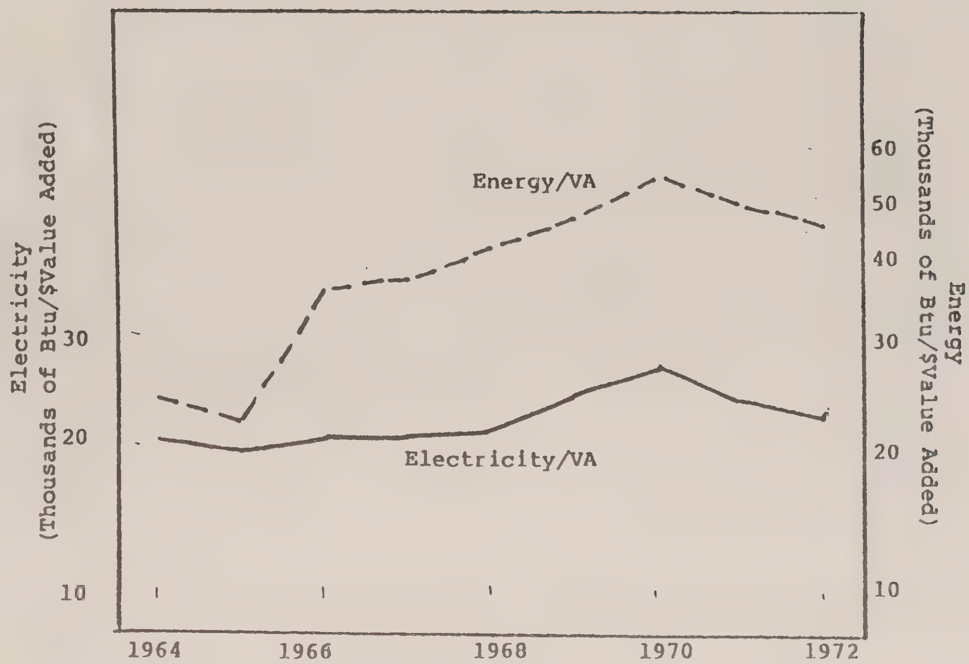
NON-METALLIC MINERAL PRODUCTS, SIC 35



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE B-18

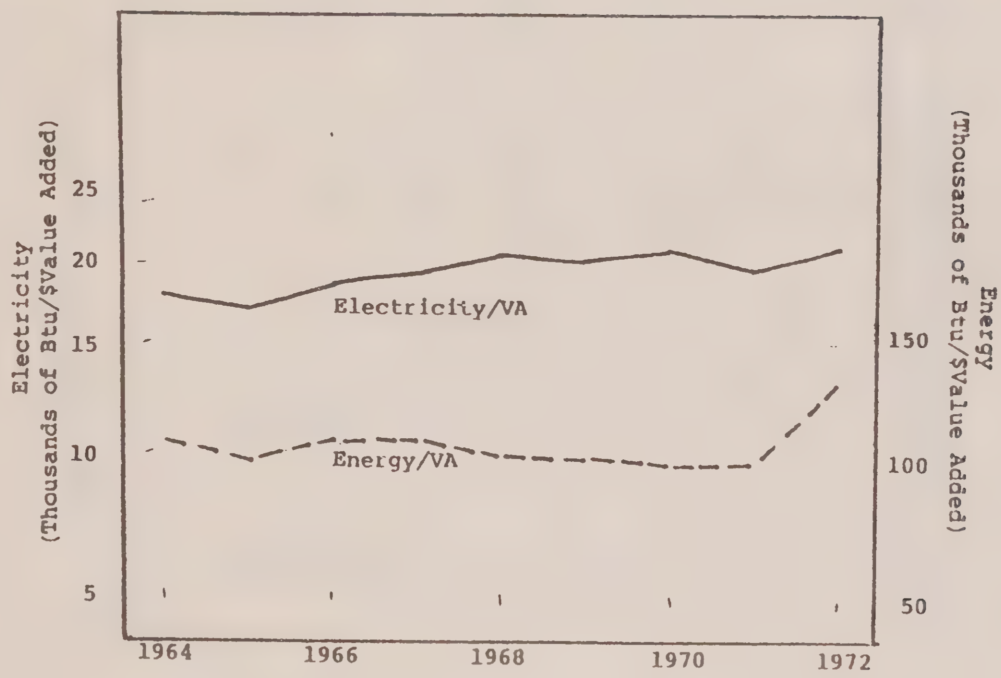
PETROLEUM AND COAL PRODUCTS, SIC 36



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

FIGURE B-19

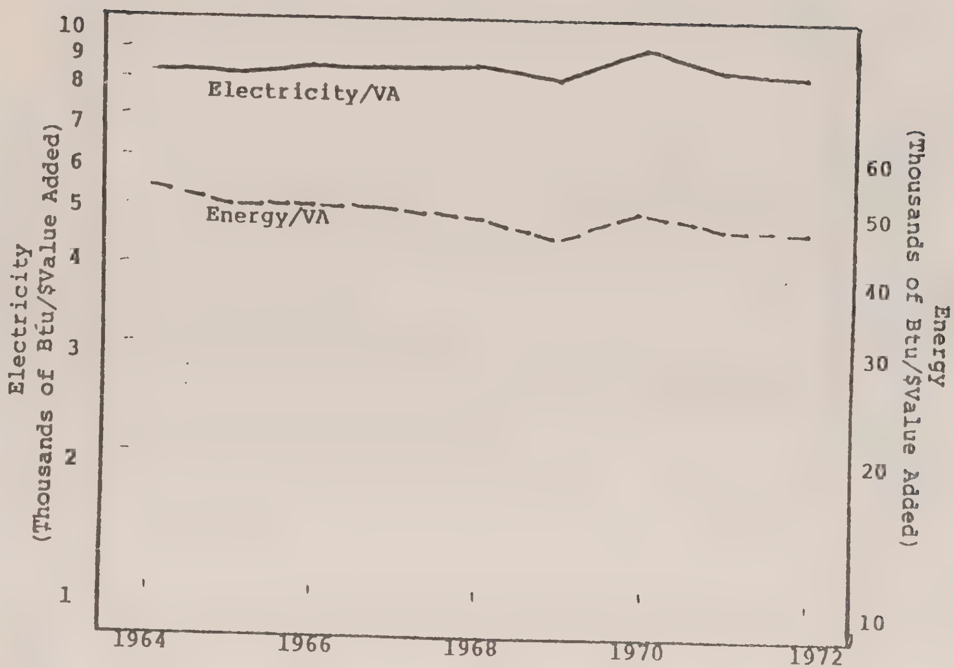
CHEMICAL AND CHEMICAL PRODUCTS, SIC 37



Source: <u>Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972</u>, Report NO: PMA-75-5.

FIGURE B-20

TOTAL MANUFACTURING



Source: Ontario Hydro, Trends in Energy Use Within Ontario Manufacturing Industries, 1964-1972, Report NO: PMA-75-5.

DATA USED IN ONTARIO HYDRO RESIDENTIAL MODEL

TABLE 1 Residential kWh consumption of electricity, 1971

Ajax	26,109,085	North York	1,070,889,179
Aurora	30,342,163	Oakville	166,093,755
Barrie	90,346,481	Orillia	57,271,950
Belleville	90,973,486	Oshawa	257,214,629
Brampton	84,611,805	Ottawa	820,609,984
Brantford	130,845,402	Owen Sound	53,996,148
Brockville	58,207,439	Pembroke	39,487,408
Burlington	211,367,763	Peterborough	174,451,388
Chatham	59,426,283	Port Colborne	29,884,184
Cobourg	31,221,483	Preston	36,428,706
Dundas	40,752,956	Richmond Hill	47,417,701
East York	205,862,748	St. Catharines	202,857,515
Etobicoke	717,359,429	St. Thomas	57,268,538
Galt	88,636,283	Sarnia	116,040,496
Georgetown	39,043,467	Scarborough	737,857,779
Grimsby	15,489,701	Simcoe	24,775,122
Guelph	166,385,369	Stratford	63,046,953
Hamilton	593,020,219	Sudbury	256,913,673
Kapuskasing	19,087,235	Thorold	15,193,707
Kenora	32,795,944	Thunder Bay	274,394,083
Kingston	145,860,019	Toronto (city)	1,166,532,848
Kitchener	248,443,982	Trenton	37,427,706
Leamington	20,796,950	Vaughan	59,128,816
Lindsay	35,710,540	Wallaceburg	18,404,240
London	435,830,509	Waterloo	87,708,818
Markham	33,871,853	Welland	64,188,065
Mississauga	404,210,416	Whitby	71,696,858
Newmarket	29,340,202	Windsor	349,989,691
Niagara Falls	109,416,848	Woodstock	64,324,524
North Bay	119,781,623	York	262,852,061

Source Ontario Hydro Statistical Yearbook, 1971.

TABLE 2 Number of residential customers, 1971

Ajax	3,390	North York	118,96[illegible]
Aurora	3,394	Oakville	15,06[illegible]
Barrie	8,284	Orillia	6,85[illegible]
Belleville	10,318	Oshawa	24,08[illegible]
Brampton	9,157	Ottawa	89,755
Brantford	18,732	Owen Sound	5,513
Brockville	6,257	Pembroke	4,501
Burlington	20,964	Peterborough	17,153
Chatham	9,679	Port Colborne	5,190
Cobourg	3,249	Preston	4,336
Dundas	4,697	Richmond Hill	4,938
East York	32,816	St. Catharines	30,236
Etobicoke	81,419	St. Thomas	8,018
Galt	9,952	Sarnia	15,366
Georgetown	4,845	Scarborough	78,608
Grimsby	2,119	Simcoe	3,559
Guelph	16,014	Stratford	7,060
Hamilton	90,302	Sudbury	25,115
Kapuskasing	1,967	Thorold	2,451
Kenora	4,081	Thunder Bay	30,478
Kingston	16,603	Toronto (city)	186,393
Kitchener	30,835	Trenton	4,482
Leamington	3,173	Vaughan	5,043
Lindsay	3,932	Wallaceburg	3,180
London	63,518	Waterloo	8,331
Markham	2,930	Welland	11,118
Mississauga	34,318	Whitby	6,478
Newmarket	3,075	Windsor	55,758
Niagara Falls	16,516	Woodstock	7,631
North Bay	13,497	York	36,514

Source Ontario Hydro Statistical Yearbook, 1971

TABLE 3 Total occupied dwellings with house heating, 1971

Ajax	3,265	North York	146,155
Aurora	3,615	Oakville	16,655
Barrie	8,335	Orillia	6,760
Belleville	10,620	Oshawa	2,645
Brampton	11,270	Ottawa	92,900
Brantford	19,415	Owen Sound	5,820
Brockville	6,275	Pembroke	4,365
Burlington	23,795	Peterborough	17,325
Chatham	10,505	Port Colborne	6,245
Cobourg	3,355	Preston	4,895
Dundas	4,925	Richmond Hill	8,680
East York	38,270	St. Catharines	32,805
Etobicoke	82,290	St. Thomas	8,050
Galt	11,270	Sarnia	16,950
Georgetown	4,490	Scarborough	91,535
Grimsby	4,460	Simcoe	3,550
Guelph	17,555	Stratford	7,650
Hamilton	94,570	Sudbury	24,455
Kapuskasing	3,235	Thorold	4,150
Kenora	3,280	Thunder Bay	31,275
Kingston	18,530	Toronto (city)	224,395
Kitchener	33,510	Trenton	4,210
Leamington	3,230	Vaughan	4,270
Lindsay	3,935	Wallaceburg	3,190
London	69,150	Waterloo	10,830
Markham	9,560	Welland	12,805
Mississauga	41,630	Whitby	6,610
Newmarket	5,060	Windsor	59,655
Niagara Falls	19,425	Woodstock	7,935
North Bay	13,025	York	46,525

Source 1971 Census of Canada

TABLE 4 Occupied dwellings where electricity principal fuel used for house heating, 1971

Ajax	155	North York	6,615
Aurora	215	Oakville	1,150
Barrie	770	Orillia	400
Belleville	1,035	Oshawa	3,050
Brampton	470	Ottawa	4,895
Brantford	950	Owen Sound	430
Brockville	725	Pembroke	75
Burlington	1,085	Peterborough	1,555
Chatham	235	Port Colborne	185
Cobourg	280	Preston	470
Dundas	160	Richmond Hill	420
East York	1,645	St. Catharines	780
Etobicoke	2,395	St. Thomas	275
Galt	1,230	Sarnia	1,310
Georgetown	145	Scarborough	4,000
Grimsby	260	Simcoe	195
Guelph	1,405	Stratford	615
Hamilton	2,890	Sudbury	1,985
Kapuskasing	425	Thorold	85
Kenora	45	Thunder Bay	1,275
Kingston	1,745	Toronto (city)	13,375
Kitchener	2,030	Trenton	310
Leamington	160	Vaughan	205
Lindsay	310	Wallaceburg	100
London	3,300	Waterloo	810
Markham	715	Welland	550
Mississauga	4,390	Whitby	640
Newmarket	330	Windsor	4,555
Niagara Falls	465	Woodstock	445
North Bay	870	York	1,525

Source 1971 Census of Canada

TABLE 5 Occupied dwellings where gas principal fuel used for house heating, 1971

Ajax	2,280	North York	62,810
Aurora	1,895	Oakville	5,655
Barrie	2,380	Orillia	2,710
Belleville	3,285	Oshawa	4,105
Brampton	6,910	Ottawa	14,585
Brantford	9,735	Owen Sound	2,845
Brockville	2,005	Pembroke	575
Burlington	11,050	Peterborough	3,630
Chatham	9,885	Port Colborne	4,320
Cobourg	1,015	Preston	2,345
Dundas	2,450	Richmond Hill	3,270
East York	12,670	St. Catharines	18,435
Etobicoke	31,790	St. Thomas	4,355
Galt	5,045	Sarnia	13,885
Georgetown	2,895	Scarborough	38,185
Grimsby	2,700	Simcoe	2,320
Guelph	8,205	Stratford	3,295
Hamilton	39,865	Sudbury	6,840
Kapuskasing	2,215	Thorold	2,290
Kenora	2,510	Thunder Bay	19,400
Kingston	2,820	Toronto (city)	82,880
Kitchener	10,385	Trenton	1,580
Leamington	2,600	Vaughan	280
Lindsay	1,510	Wallaceburg	2,970
London	47,695	Waterloo	5,000
Markham	2,735	Welland	9,905
Mississauga	22,370	Whitby	1,410
Newmarket	2,145	Windsor	47,750
Niagara Falls	13,310	Woodstock	4,300
North Bay	6,000	York	14,535

Source 1971 Census of Canada

TABLE 6 Total occupied dwellings with water heating, 1971

Ajax	3,265	North York	146,160
Aurora	3,610	Oakville	16,655
Barrie	8,335	Orillia	6,765
Belleville	10,620	Oshawa	26,450
Brampton	11,270	Ottawa	92,905
Brantford	19,415	Owen Sound	5,815
Brockville	6,275	Pembroke	4,570
Burlington	23,795	Peterborough	17,325
Chatham	10,505	Port Colborne	6,245
Cobourg	3,355	Preston	4,895
Dundas	4,925	Richmond Hill	8,680
East York	38,275	St. Catharines	32,805
Etobicoke	82,290	St. Thomas	8,050
Galt	11,270	Sarnia	16,955
Georgetown	4,490	Scarborough	91,535
Grimsby	4,460	Simcoe	3,550
Guelph	17,555	Stratford	7,655
Hamilton	94,575	Sudbury	24,455
Kapuskasing	3,235	Thorold	4,155
Kenora	3,275	Thunder Bay	31,275
Kingston	18,535	Toronto (city)	224,395
Kitchener	33,515	Trenton	4,215
Leamington	3,225	Vaughan	4,270
Lindsay	3,935	Wallaceburg	3,195
London	69,155	Waterloo	10,830
Markham	9,565	Welland	12,800
Mississauga	41,630	Whitby	6,610
Newmarket	5,060	Windsor	59,660
Niagara Falls	19,420	Woodstock	7,930
North Bay	13,025	York	46,525

Source 1971 Census of Canada

TABLE 7 Occupied dwellings where electricity principal fuel used for water heating, 1971

Ajax	910	North York	70,260
Aurora	1,835	Oakville	10,660
Barrie	6,195	Orillia	4,595
Belleville	8,185	Oshawa	21,470
Brampton	5,745	Ottawa	71,545
Brantford	9,230	Owen Sound	4,535
Brockville	4,885	Pembroke	3,625
Burlington	11,995	Peterborough	13,855
Chatham	1,865	Port Colborne	1,425
Cobourg	2,595	Preston	2,740
Dundas	2,785	Richmond Hill	5,490
East York	18,550	St. Catharines	11,755
Etobicoke	43,960	St. Thomas	3,965
Galt	6,855	Sarnia	3,800
Georgetown	1,955	Scarborough	45,500
Grimsby	1,825	Simcoe	1,365
Guelph	10,665	Stratford	5,500
Hamilton	40,950	Sudbury	18,410
Kapuskasing	1,475	Thorold	1,445
Kenora	1,575	Thunder Bay	17,730
Kingston	14,595	Toronto (city)	96,330
Kitchener	23,150	Trenton	3,175
Leamington	875	Vaughan	3,850
Lindsay	2,590	Wallaceburg	500
London	27,205	Waterloo	6,385
Markham	6,725	Welland	1,900
Mississauga	18,890	Whitby	5,185
Newmarket	2,935	Windsor	12,990
Niagara Falls	5,765	Woodstock	4,980
North Bay	7,935	York	24,695

Source 1971 Census of Canada

TABLE 8 Occupied dwellings where gas principal fuel used for water heating, 1971

Ajax	2,140	North York	56,720
Aurora	1,680	Oakville	5,205
Barrie	1,775	Orillia	2,010
Belleville	2,065	Oshawa	3,755
Brampton	5,000	Ottawa	11,885
Brantford	9,550	Owen Sound	1,125
Brockville	1,230	Pembroke	550
Burlington	10,690	Peterborough	2,970
Chatham	8,560	Port Colborne	4,735
Cobourg	705	Preston	2,090
Dundas	2,020	Richmond Hill	2,940
East York	13,480	St. Catharines	19,680
Etobicoke	29,955	St. Thomas	3,930
Galt	4,170	Sarnia	12,910
Georgetown	2,475	Scarborough	36,900
Grimsby	2,570	Simcoe	2,145
Guelph	6,355	Stratford	1,965
Hamilton	47,520	Sudbury	4,600
Kapuskasing	1,655	Thorold	2,630
Kenora	1,670	Thunder Bay	12,790
Kingston	1,970	Toronto (city)	96,240
Kitchener	8,290	Trenton	855
Leamington	2,340	Vaughan	325
Lindsay	1,220	Wallaceburg	2,675
London	39,915	Waterloo	3,880
Markham	2,445	Welland	10,715
Mississauga	20,545	Whitby	1,210
Newmarket	1,975	Windsor	45,885
Niagara Falls	13,235	Woodstock	2,865
North Bay	4,620	York	15,375

Source 1971 Census of Canada

TABLE 9 Total occupied dwellings with cooking facilities, 1971

Ajax	3,270	North York	146,165
Aurora	3,610	Oakville	16,655
Barrie	8,340	Orillia	6,760
Belleville	10,620	Oshawa	26,445
Brampton	11,275	Ottawa	92,905
Brantford	19,410	Owen Sound	5,815
Brockville	6,280	Pembroke	4,575
Burlington	23,795	Peterborough	17,325
Chatham	10,505	Port Colborne	6,245
Cobourg	3,355	Preston	4,895
Dundas	4,925	Richmond Hill	8,680
East York	38,275	St. Catharines	32,805
Etobicoke	82,295	St. Thomas	8,050
Galt	11,270	Sarnia	16,955
Georgetown	4,485	Scarborough	91,535
Grimsby	4,460	Simcoe	3,550
Guelph	17,560	Stratford	7,650
Hamilton	94,580	Sudbury	24,455
Kapuskasing	3,240	Thorold	4,150
Kenora	3,275	Thunder Bay	31,275
Kingston	18,540	Toronto (city)	224,395
Kitchener	33,515	Trenton	4,210
Leamington	3,225	Vaughan	4,270
Lindsay	3,930	Wallaceburg	3,195
London	69,155	Waterloo	10,830
Markham	9,565	Welland	12,805
Mississauga	41,635	Whitby	6,605
Newmarket	5,060	Windsor	59,655
Niagara Falls	19,425	Woodstock	7,935
North Bay	13,025	York	46,525

Source 1971 Census of Canada

TABLE 10 Occupied dwellings where electricity principal fuel used for cooking, 1971

Ajax	2,570	North York	136,830
Aurora	3,130	Oakville	15,060
Barrie	7,750	Orillia	5,900
Belleville	9,755	Oshawa	25,045
Brampton	10,215	Ottawa	89,510
Brantford	14,200	Owen Sound	5,360
Brockville	5,240	Pembroke	4,055
Burlington	21,735	Peterborough	16,040
Chatham	5,595	Port Colborne	2,470
Cobourg	3,085	Preston	4,070
Dundas	4,005	Richmond Hill	7,595
East York	32,665	St. Catharines	26,395
Etobicoke	76,780	St. Thomas	6,485
Galt	9,455	Sarnia	10,820
Georgetown	3,995	Scarborough	84,095
Grimsby	3,600	Simcoe	1,820
Guelph	14,920	Stratford	7,055
Hamilton	72,555	Sudbury	23,425
Kapuskasing	3,075	Thorold	2,780
Kenora	3,015	Thunder Bay	29,805
Kingston	17,215	Toronto (city)	144,915
Kitchener	32,050	Trenton	3,835
Leamington	1,860	Vaughan	4,035
Lindsay	3,555	Wallaceburg	1,145
London	50,885	Waterloo	10,310
Markham	9,040	Welland	5,130
Mississauga	38,070	Whitby	6,105
Newmarket	4,500	Windsor	40,110
Niagara Falls	14,605	Woodstock	6,655
North Bay	11,675	York	37,320

Source 1971 Census of Canada

TABLE 11 Occupied dwellings where gas principal fuel used for cooking, 1971

Ajax	675	North York	8,445
Aurora	455	Oakville	1,505
Barrie	515	Orillia	790
Belleville	775	Oshawa	1,185
Brampton	995	Ottawa	2,620
Brantford	5,120	Owen Sound	395
Brockville	975	Pembroke	320
Burlington	1,970	Peterborough	1,175
Chatham	4,865	Port Colborne	3,730
Cobourg	240	Preston	800
Dundas	910	Richmond Hill	1,010
East York	5,345	St. Catharines	6,275
Etobicoke	5,065	St. Thomas	1,535
Galt	1,765	Sarnia	6,085
Georgetown	490	Scarborough	6,940
Grimsby	840	Simcoe	1,720
Guelph	2,535	Stratford	550
Hamilton	21,475	Sudbury	780
Kapuskasing	150	Thorold	1,355
Kenora	235	Thunder Bay	1,030
Kingston	1,205	Toronto (city)	77,040
Kitchener	1,235	Trenton	335
Leamington	1,360	Vaughan	205
Lindsay	345	Wallaceburg	2,035
London	17,955	Waterloo	485
Markham	425	Welland	7,610
Mississauga	3,370	Whitby	445
Newmarket	535	Windsor	19,275
Niagara Falls	4,730	Woodstock	1,250
North Bay	1,225	York	8,720

Source 1971 Census of Canada

TABLE 12 Typical net electricity bill, 250 kWh, July 1, 1971, $

Ajax	5.80	North York	5.85
Aurora	5.60	Oakville	7.40
Barrie	5.63	Orillia	4.20
Belleville	5.00	Oshawa	6.25
Brampton	7.30	Ottawa	3.95
Brantford	5.65	Owen Sound	5.00
Brockville	5.90	Pembroke	6.25
Burlington	7.20	Peterborough	6.55
Chatham	5.60	Port Colborne	5.70
Cobourg	4.30	Preston	5.60
Dundas	6.30	Richmond Hill	5.00
East York	4.80	St. Catharines	6.20
Etobicoke	5.03	St. Thomas	6.25
Galt	6.20	Sarnia	5.60
Georgetown	5.80	Scarborough	4.99
Grimsby	4.90	Simcoe	6.00
Guelph	5.60	Stratford	6.65
Hamilton	4.65	Sudbury	4.55
Kapuskasing	4.70	Thorold	5.58
Kenora	4.35	Thunder Bay	4.80
Kingston	4.40	Toronto (city)	4.49
Kitchener	5.00	Trenton	4.30
Leamington	5.25	Vaughan	7.10
Lindsay	6.00	Wallaceburg	4.85
London	6.90	Waterloo	6.90
Markham	7.30	Welland	6.00
Mississauga	6.25	Whitby	6.05
Newmarket	5.85	Windsor	6.30
Niagara Falls	5.70	Woodstock	5.85
North Bay	5.20	York	4.75

Source Typical bills and monthly rates, Ontario Hydro and the associated municipal utilities, July 1971.

TABLE 13 Typical net electricity bill, 500 kWh, July 1, 1971, $

Ajax	7.80	North York	8.43
Aurora	7.60	Oakville	9.65
Barrie	8.56	Orillia	7.15
Belleville	7.25	Oshawa	8.50
Brampton	9.55	Ottawa	5.45
Brantford	7.65	Owen Sound	7.00
Brockville	8.03	Pembroke	8.25
Burlington	9.20	Peterborough	8.83
Chatham	8.18	Port Colborne	7.70
Cobourg	6.05	Preston	7.73
Dundas	8.30	Richmond Hill	6.75
East York	7.36	St. Catharines	8.20
Etobicoke	8.36	St. Thomas	8.25
Galt	8.35	Sarnia	7.35
Georgetown	7.80	Scarborough	7.52
Grimsby	6.90	Simcoe	8.00
Guelph	7.50	Stratford	8.65
Hamilton	8.15	Sudbury	6.55
Kapuskasing	6.98	Thorold	7.38
Kenora	6.35	Thunder Bay	6.30
Kingston	7.03	Toronto (city)	7.88
Kitchener	7.00	Trenton	6.30
Leamington	7.13	Vaughan	9.23
Lindsay	9.50	Wallaceburg	6.85
London	8.65	Waterloo	9.15
Markham	9.55	Welland	8.00
Mississauga	8.25	Whitby	8.05
Newmarket	8.10	Windsor	8.55
Niagara Falls	7.45	Woodstock	7.73
North Bay	7.45	York	7.65

Source Typical bills and monthly rates, Ontario Hydro and the associated municipalities, July 1971.

TABLE 14 Typical net electricity bill, 1,000 kWh, July 1, 1971, $

Ajax	12.43	North York	12.08
Aurora	12.23	Oakville	14.65
Barrie	12.16	Orillia	10.60
Belleville	12.25	Oshawa	13.50
Brampton	14.55	Ottawa	8.45
Brantford	12.28	Owen Sound	11.50
Brockville	12.78	Pembroke	13.00
Burlington	13.83	Peterborough	12.41
Chatham	11.58	Port Colborne	12.33
Cobourg	10.30	Preston	12.48
Dundas	13.05	Richmond Hill	11.00
East York	10.74	St. Catharines	12.83
Etobicoke	11.87	St. Thomas	12.75
Galt	12.03	Sarnia	11.60
Georgetown	12.30	Scarborough	10.94
Grimsby	11.53	Simcoe	12.50
Guelph	10.90	Stratford	13.15
Hamilton	11.65	Sudbury	11.18
Kapuskasing	10.18	Thorold	11.88
Kenora	10.85	Thunder Bay	10.05
Kingston	12.28	Toronto (city)	11.40
Kitchener	11.50	Trenton	10.93
Leamington	11.63	Vaughan	14.10
Lindsay	12.75	Wallaceburg	11.35
London	12.90	Waterloo	14.15
Markham	14.68	Welland	12.63
Mississauga	12.93	Whitby	12.80
Newmarket	13.35	Windsor	13.68
Niagara Falls	11.45	Woodstock	12.23
North Bay	12.45	York	11.03

Source Typical bills and monthly rates, Ontario Hydro and the associated municipalities, July 1971.

TABLE 15 Typical net electricity bill, 20,000 kWh, July 1, 1971, $

Ajax	227.70	North York	231.40
Aurora	225.30	Oakville	248.80
Barrie	216.00	Orillia	220.00
Belleville	237.00	Oshawa	247.00
Brampton	249.40	Ottawa	199.40
Brantford	225.90	Owen Sound	213.20
Brockville	230.70	Pembroke	237.40
Burlington	252.40	Peterborough	236.70
Chatham	212.00	Port Colborne	225.30
Cobourg	206.60	Preston	227.70
Dundas	235.60	Richmond Hill	206.00
East York	218.70	St. Catharines	240.40
Etobicoke	264.07	St. Thomas	218.00
Galt	227.70	Sarnia	222.20
Georgetown	218.00	Scarborough	222.70
Grimsby	216.30	Simcoe	232.00
Guelph	234.80	Stratford	239.80
Hamilton	233.20	Sudbury	210.00
Kapuskasing	226.16	Thorold	232.56
Kenora	212.20	Thunder Bay	195.60
Kingston	231.30	Toronto (city)	232.99
Kitchener	218.00	Trenton	217.60
Leamington	221.70	Vaughan	259.70
Lindsay	237.40	Wallaceburg	218.20
London	221.00	Waterloo	243.40
Markham	253.10	Welland	227.70
Mississauga	243.40	Whitby	237.40
Newmarket	240.00	Windsor	253.10
Niagara Falls	216.65	Woodstock	227.70
North Bay	231.40	York	241.50

Source Typical bills and monthly rates, Ontario Hydro and the associated municipal utilities, July 1971.

TABLE 16 Typical net electricity bill, 30,000 kWh, July 1, 1971, $

Ajax	332.70	North York	341.40
Aurora	330.30	Oakville	358.80
Barrie	324.00	Orillia	330.00
Belleville	346.00	Oshawa	357.00
Brampton	359.40	Ottawa	305.65
Brantford	330.90	Owen Sound	313.20
Brockville	335.70	Pembroke	347.40
Burlington	356.15	Peterborough	341.70
Chatham	312.00	Port Colborne	330.30
Cobourg	305.10	Preston	332.70
Dundas	345.60	Richmond Hill	306.00
East York	323.70	St. Catharines	344.15
Etobicoke	367.03	St. Thomas	318.00
Galt	332.70	Sarnia	320.70
Georgetown	318.00	Scarborough	328.00
Grimsby	321.30	Simcoe	331.00
Guelph	322.80	Stratford	338.80
Hamilton	343.20	Sudbury	315.00
Kapuskasing	314.16	Thorold	338.76
Kenora	311.20	Thunder Bay	284.10
Kingston	336.30	Toronto (city)	329.40
Kitchener	318.00	Trenton	321.35
Leamington	326.70	Vaughan	368.45
Lindsay	347.40	Wallaceburg	317.20
London	321.00	Waterloo	353.40
Markham	366.10	Welland	332.70
Mississauga	349.05	Whitby	347.40
Newmarket	360.00	Windsor	368.10
Niagara Falls	313.95	Woodstock	332.70
North Bay	341.40	York	333.90

Source: Typical bills and monthly rates, Ontario Hydro and the associated municipal utilities, July 1971.

TABLE 17 Typical net gas bill, 100 cubic feet, 1971 ,$

Ajax	13.93	North York	13.93
Aurora	13.93	Oakville	13.53
Barrie	13.93	Orillia	13.65
Belleville	14.51	Oshawa	13.93
Brampton	13.93	Ottawa	13.93
Brantford	10.95	Owen Sound	13.53
Brockville	13.93	Pembroke	13.93
Burlington	13.53	Peterborough	13.93
Chatham	10.95	Port Colborne	11.27
Cobourg	14.51	Preston	13.53
Dundas	13.53	Richmond Hill	13.93
East York	13.93	St. Catharines	11.27
Etobicoke	13.93	St. Thomas	10.95
Galt	13.53	Sarnia	10.95
Georgetown	13.53	Scarborough	13.93
Grimsby	14.20	Simcoe	10.95
Guelph	13.53	Stratford	13.53
Hamilton	13.53	Sudbury	13.65
Kapuskasing	13.65	Thorold	11.27
Kenora	12.60	Thunder Bay	12.60
Kingston	14.66	Toronto (city)	13.93
Kitchener	12.83	Trenton	14.51
Leamington	10.95	Vaughan	13.93
Lindsay	13.93	Wallaceburg	10.95
London	10.95	Waterloo	13.53
Markham	13.93	Welland	11.27
Mississauga	13.93	Whitby	13.93
Newmarket	13.93	Windsor	10.95
Niagara Falls	11.27	Woodstock	10.95
North Bay	13.65	York	13.93

Source The various gas companies (See Appendix 2)

TABLE 18 Average income of individuals 15 years and over, 1970, $

Ajax	4,745	North York	5,363
Aurora	4,630	Oakville	5,361
Barrie	4,183	Orillia	4,045
Belleville	4,141	Oshawa	4,327
Brampton	4,894	Ottawa	4,944
Brantford	3,961	Owen Sound	3,914
Brockville	4,333	Pembroke	3,499
Burlington	5,309	Peterborough	4,231
Chatham	4,119	Port Colborne	3,885
Cobourg	3,886	Preston	4,173
Dundas	4,838	Richmond Hill	4,563
East York	4,817	St. Catharines	4,114
Etobicoke	5,233	St. Thomas	4,105
Galt	4,004	Sarnia	4,670
Georgetown	4,921	Scarborough	4,740
Grimsby	4,325	Simcoe	4,267
Guelph	4,282	Stratford	4,115
Hamilton	4,112	Sudbury	4,839
Kapuskasing	4,204	Thorold	3,755
Kenora	4,062	Thunder Bay	3,997
Kingston	4,304	Toronto (city)	4,531
Kitchener	4,410	Trenton	3,908
Leamington	3,806	Vaughan	5,418
Lindsay	3,773	Wallaceburg	3,839
London	4,546	Waterloo	4,805
Markham	5,862	Welland	3,967
Mississauga	5,522	Whitby	4,119
Newmarket	4,297	Windsor	4,566
Niagara Falls	3,996	Woodstock	4,178
North Bay	4,059	York	4,268

Source 1971 Census of Canada

TABLE 19 Percentage of individuals 15 years and over with income less than $3,000, 1970

Ajax	24.37	North York	26.39
Aurora	26.60	Oakville	26.55
Barrie	33.09	Orillia	33.69
Belleville	31.17	Oshawa	26.59
Brampton	26.61	Ottawa	29.51
Brantford	34.04	Owen Sound	37.16
Brockville	29.96	Pembroke	35.46
Burlington	26.32	Peterborough	32.52
Chatham	33.92	Port Colborne	30.19
Cobourg	32.37	Preston	32.23
Dundas	30.51	Richmond Hill	28.47
East York	27.58	St. Catharines	30.40
Etobicoke	26.70	St. Thomas	32.04
Galt	31.31	Sarnia	29.15
Georgetown	23.32	Scarborough	26.93
Grimsby	31.13	Simcoe	36.96
Guelph	30.28	Stratford	33.81
Hamilton	30.19	Sudbury	26.19
Kapuskasing	25.36	Thorold	30.75
Kenora	35.56	Thunder Bay	32.68
Kingston	32.89	Toronto (city)	30.53
Kitchener	29.97	Trenton	29.28
Leamington	39.50	Vaughan	28.04
Lindsay	38.24	Wallaceburg	35.31
London	30.78	Waterloo	31.72
Markham	26.02	Welland	30.18
Mississauga	23.98	Whitby	28.35
Newmarket	33.80	Windsor	29.46
Niagara Falls	34.26	Woodstock	31.43
North Bay	28.87	York	26.81

Source 1971 Census of Canada

TABLE 20 Total occupied dwellings, 1971

Ajax	3,260	North York	146,175
Aurora	3,610	Oakville	16,700
Barrie	8,300	Orillia	6,760
Belleville	10,620	Oshawa	26,480
Brampton	11,275	Ottawa	92,810
Brantford	19,405	Owen Sound	5,855
Brockville	6,265	Pembroke	4,550
Burlington	23,805	Peterborough	17,365
Chatham	10,530	Port Colborne	6,245
Cobourg	3,395	Preston	4,890
Dundas	4,930	Richmond Hill	8,680
East York	38,290	St. Catharines	32,850
Etobicoke	82,295	St. Thomas	8,065
Galt	11,260	Sarnia	16,965
Georgetown	4,490	Scarborough	91,525
Grimsby	4,460	Simcoe	3,550
Guelph	17,570	Stratford	7,625
Hamilton	94,590	Sudbury	24,440
Kapuskasing	3,240	Thorold	4,155
Kenora	3,290	Thunder Bay	31,245
Kingston	18,500	Toronto (city)	224,440
Kitchener	33,505	Trenton	4,180
Leamington	3,225	Vaughan	4,270
Lindsay	3,930	Wallaceburg	3,205
London	69,130	Waterloo	10,835
Markham	9,555	Welland	12,800
Mississauga	41,635	Whitby	6,630
Newmarket	5,055	Windsor	59,740
Niagara Falls	19,445	Woodstock	7,930
North Bay	13,060	York	147,301

Source 1971 Census of Canada

TABLE 21 Number of occupied dwellings built 1961 to 1971 inclusive, 1971

Ajax	1,370	North York	72,810
Aurora	1,145	Oakville	6,225
Barrie	2,585	Orillia	1,495
Belleville	2,670	Oshawa	9,445
Brampton	6,125	Ottawa	28,250
Brantford	3,695	Owen Sound	790
Brockville	1,335	Pembroke	500
Burlington	11,525	Peterborough	3,385
Chatham	2,250	Port Colborne	955
Cobourg	665	Preston	1,675
Dundas	1,410	Richmond Hill	1,725
East York	10,095	St. Catharines	9,250
Etobicoke	28,430	St. Thomas	1,460
Galt	3,375	Sarnia	4,000
Georgetown	1,835	Scarborough	35,420
Grimsby	1,560	Simcoe	735
Guelph	5,920	Stratford	1,570
Hamilton	22,295	Sudbury	5,905
Kapuskasing	775	Thorold	640
Kenora	445	Thunder Bay	6,315
Kingston	5,300	Toronto (city)	40,145
Kitchener	12,935	Trenton	955
Leamington	400	Vaughan	835
Lindsay	615	Wallaceburg	485
London	23,585	Waterloo	5,145
Markham	5,550	Welland	2,605
Mississauga	26,385	Whitby	1,765
Newmarket	1,500	Windsor	10,620
Niagara Falls	3,945	Woodstock	1,970
North Bay	3,540	York	8,160

Source 1971 Census of Canada

TABLE 22 Number of occupied dwellings with piped hot and cold water in dwelling, 1971

Ajax	3,245	North York	145,635
Aurora	3,580	Oakville	16,540
Barrie	8,210	Orillia	6,610
Belleville	10,320	Oshawa	26,280
Brampton	11,205	Ottawa	92,040
Brantford	19,190	Owen Sound	5,760
Brockville	6,190	Pembroke	4,350
Burlington	23,660	Peterborough	17,155
Chatham	10,375	Port Colborne	6,130
Cobourg	3,355	Preston	4,840
Dundas	4,895	Richmond Hill	8,475
East York	38,090	St. Catharines	32,610
Etobicoke	81,390	St. Thomas	7,995
Galt	11,135	Sarnia	16,860
Georgetown	9,470	Scarborough	91,035
Grimsby	4,395	Simcoe	3,506
Guelph	17,385	Stratford	7,520
Hamilton	93,870	Sudbury	28,175
Kapuskasing	3,160	Thorold	4,090
Kenora	3,060	Thunder Bay	30,500
Kingston	18,340	Toronto (city)	222,235
Kitchener	33,190	Trenton	4,055
Leamington	3,180	Vaughan	4,130
Lindsay	3,845	Wallaceburg	3,130
London	68,675	Waterloo	10,760
Markham	9,440	Welland	12,665
Mississauga	41,360	Whitby	6,515
Newmarket	5,025	Windsor	59,280
Niagara Falls	19,225	Woodstock	7,855
North Bay	12,850	York	46,175

Source 1971 Census of Canada

TABLE 23 Number of occupied dwellings with piped cold water only in dwelling, 1971

Ajax	15	North York	330
Aurora	25	Oakville	100
Barrie	50	Orillia	105
Belleville	195	Oshawa	145
Brampton	40	Ottawa	440
Brantford	165	Owen Sound	75
Brockville	60	Pembroke	190
Burlington	90	Peterborough	135
Chatham	115	Port Colborne	55
Cobourg	30	Preston	40
Dundas	25	Richmond Hill	135
East York	145	St. Catharines	185
Etobicoke	275	St. Thomas	65
Galt	100	Sarnia	90
Georgetown	10	Scarborough	370
Grimsby	35	Simcoe	30
Guelph	150	Stratford	90
Hamilton	555	Sudbury	190
Kapuskasing	45	Thorold	40
Kenora	85	Thunder Bay	390
Kingston	115	Toronto (city)	985
Kitchener	260	Trenton	100
Leamington	45	Vaughan	60
Lindsay	60	Wallaceburg	60
London	330	Waterloo	60
Markham	60	Welland	90
Mississauga	170	Whitby	55
Newmarket	25	Windsor	360
Niagara Falls	160	Woodstock	70
North Bay	120	York	205

Source 1971 Census of Canada

TABLE 24 Total apartments, 1971

Ajax	340	North York	59,130
Aurora	410	Oakville	3,100
Barrie	1,970	Orillia	1,115
Belleville	2,485	Oshawa	6,135
Brampton	2,790	Ottawa	34,350
Brantford	3,675	Owen Sound	1,390
Brockville	1,480	Pembroke	1,035
Burlington	5,025	Peterborough	2,960
Chatham	2,155	Port Colborne	850
Cobourg	865	Preston	1,230
Dundas	945	Richmond Hill	980
East York	16,445	St. Catharines	6,300
Etobicoke	24,950	St. Thomas	1,700
Galt	2,715	Sarnia	3,315
Georgetown	480	Scarborough	26,265
Grimsby	550	Simcoe	810
Guelph	4,580	Stratford	1,750
Hamilton	27,770	Sudbury	7,040
Kapuskasing	850	Thorold	505
Kenora	405	Thunder Bay	4,765
Kingston	7,455	Toronto (city)	94,015
Kitchener	10,415	Trenton	815
Leamington	460	Vaughan	205
Lindsay	780	Wallaceburg	335
London	20,105	Waterloo	3,215
Markham	940	Welland	2,290
Mississauga	10,300	Whitby	1,085
Newmarket	720	Windsor	11,365
Niagara Falls	3,085	Woodstock	1,455
North Bay	2,445	York	17,640

Source 1971 Census of Canada

TABLE 25 Heating degree days - normal

Ajax	7,500	North York	7,008
Aurora	7,900	Oakville	6,700
Barrie	8,200	Orillia	8,463
Belleville	7,709	Oshawa	7,600
Brampton	7,721	Ottawa	8,760
Brantford	7,202	Owen Sound	7,762
Brockville	7,900	Pembroke	9,100
Burlington	6,800	Peterborough	8,300
Chatham	6,503	Port Colborne	6,700
Cobourg	7,700	Preston	7,700
Dundas	7,150	Richmond Hill	7,700
East York	7,008	St. Catherines	6,537
Etobicoke	7,008	St. Thomas	7,073
Galt	7,600	Sarnia	7,081
Georgetown	7,817	Scarborough	7,700
Grimsby	6,592	Simcoe	7,419
Guelph	7,749	Stratford	8,000
Hamilton	7,043	Sudbury	10,000
Kapuskasing	11,905	Thorold	7,800
Kenora	10,962	Thunder Bay	10,686
Kingston	7,724	Toronto (city)	6,773
Kitchener	7,566	Trenton	7,910
Leamington	6,547	Vaughan	7,800
Lindsay	8,400	Wallaceburg	6,668
London	7,744	Waterloo	7,566
Markham	7,200	Welland	6,691
Mississauga	7,100	Whitby	7,500
Newmarket	7,300	Windsor	6,754
Niagara Falls	6,881	Woodstock	7,542
North Bay	9,894	York	7,008

Source Senior Meteorologist, Power Systems Operations Division, Ontario Hydro.

TABLE 26 Heating degree days - deviation from normal in 1971

Ajax	-5	North York	-10
Aurora	40	Oakville	-25
Barrie	80	Orillia	100
Belleville	110	Oshawa	-10
Brampton	5	Ottawa	137
Brantford	-70	Owen Sound	5
Brockville	120	Pembroke	275
Burlington	-30	Peterborough	130
Chatham	-130	Port Colborne	-140
Cobourg	30	Preston	-60
Dundas	-30	Richmond Hill	10
East York	-10	St. Catherines	-40
Etobicoke	-10	St. Thomas	-150
Galt	-60	Sarnia	-140
Georgetown	5	Scarborough	-5
Grimsby	-40	Simcoe	-175
Guelph	-50	Stratford	-80
Hamilton	-14	Sudbury	7
Kapuskasing	-248	Thorold	-60
Kenora	-127	Thunder Bay	-264
Kingston	115	Toronto (city)	-47
Kitchener	-60	Trenton	80
Leamington	-160	Vaughan	20
Lindsay	110	Wallaceburg	-130
London	-119	Waterloo	-60
Markham	-5	Welland	-100
Mississauga	20	Whitby	-10
Newmarket	25	Windsor	-156
Niagara Falls	-75	Woodstock	-90
North Bay	-31	York	-10

Source Senior Meteorologist, Power Systems Operations Division, Ontario Hydro.